Vision Sciences Society

12th Annual Meeting, May 11-16, 2012

Waldorf Astoria Naples, Naples, Florida

Abstracts

Contents

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Sessions Overview

Abstract Numbering System

Each abstract is assigned a unique 4 to 5 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).

First Digit - Day	Second Digit - Time Period	Third Digit - Room	Fourth/Fifth Digits - Number
1 Friday	1 Early AM talk session	1 Royal Palm 1-3	1, 2, 3... For talks
2 Saturday	2 Late AM talk session	2 Royal Palm 4-5	01, 02, 03... For posters
3 Sunday	3 AM poster session	3 Royal Palm 6-8	
4 Monday	4 Early PM talk session	4 Orchid Ballroom	
5 Tuesday	5 Late PM talk session	5 Vista Ballroom	
6 Wednesday	6 PM poster session		

Examples:
21.16 Saturday, early AM talk in Royal Palm 1-3, 6th talk
36.513 Sunday, PM poster in Vista Ballroom, poster board 513
53.306 Tuesday, AM poster in Royal Palm 6-8, poster board 306

Note: Two digits after the period indicates a talk, three digits indicates a poster (and is also the number of the poster board).

Member-Initiated Symposia

See the Abstracts book for the full symposium description and the text of each presentation. Symposium rooms have limited capacity and fill up quickly, so plan to arrive early.

Schedule Overview

Friday, May 11, 1:00 – 3:00 pm

S1 Pulvinar and Vision: New insights into circuitry and function, Royal Palm 1-3

S2 What does fMRI tell us about brain homologies?, Royal Palm 4-5

S3 Part-whole relationships in visual cortex, Royal Palm 6-8

Friday, May 11, 3:30 – 5:30 pm

S4 Distinguishing perceptual shifts from response biases, Royal Palm 1-3

S5 Human visual cortex: from receptive fields to maps to clusters to perception, Royal Palm 4-5

S6 Neuromodulation of Visual Perception, Royal Palm 6-8

S1
Pulvinar and Vision: New insights into circuitry and function

Friday, May 11, 1:00 - 3:00 pm, Royal Palm 1-3

Organizer: Vivien A. Casagrande, PhD, Department of Cell & Developmental Biology, Vanderbilt Medical School Nashville, TN

Presenters: Gopathy Purushothaman, Department of Cell & Developmental Biology Vanderbilt Medical School; Christian Casanova,University of Montreal, Sch Optometry, Montreal , Canada; Heywood M. Petry, Department of Psychological & Brain Sciences, University of Louisville; Robert H. Wurtz, NIH-NEI, Lab of Sensorimotor Research, Sabine Kastner, MD, Department of Psychology, Center for Study of Brain, Mind and Behavior, Green Hall, Princeton; David Whitney,Department of Psychology, University of California, Berkeley

Symposium Summary

The most mysterious nucleus of the visual thalamus is the pulvinar. In most mammals the pulvinar is the largest thalamic nucleus, and it has progressively enlarged in primate evolution so that it dwarfs the remainder of the thalamus in humans. Despite the large size of the pulvinar, relatively little is known regarding its function, and consequently its potential influence on cortical activity patterns is unappreciated. This symposium will outline new insights regarding the role of the pulvinar nucleus in vision, and should provide the VSS audience with a new appreciation of the interactions between the pulvinar nucleus and cortex.

Presentations

Gating of the Primary Visual Cortex by Pulvinar for Controlling Bottom-Up Salience

Gopathy Purushothaman, PhD, Department of Cell & Developmental Biology Vanderbilt Medical School, Roan Marion, Keji Li and Vivien A. Casagrande, Vanderbilt University

The thalamic nucleus pulvinar has been implicated in the control of visual attention. Its reciprocal connections with both frontal and sensory cortices can coordinate top-down and bottom-up processes for selective visual attention. However, pulvino-cortical neural interactions are little understood. We recently found that the lateral pulvinar (PL) powerfully controls stimulus-driven responses in the primary visual cortex (V1). Reversibly inactivating PL abolished visual responses in supra-granular layers of V1. Excitation of PL neurons responsive to one region of visual space increased 4-fold V1 responses to this region and decreased 3-fold V1 responses to the surrounding region. Glutamate agonist injection in LGN increased V1 activity 8-fold and induced an excitotoxic lesion of LGN; subsequently injecting the glutamate agonist into PL increased V1 activity 14-fold. Spontaneous activity in PL and V1 following visual stimulation were strongly coupled and selectively entrained at the stimulation frequency. These results suggest that PL-V1 interactions are well-suited to control bottom-up salience within a competitive cortico-pulvino-cortical network for selective attention.

Is The Pulvinar Driving or Modulating Responses in the Visual Cortex?

Christian Casanova, PhD, Univ. Montreal, Sch Optometry, Montreal , Canada, Matthieu Vanni & Reza F. Abbas & Sébastien Thomas. Visual Neuroscience Laboratory, School of Optometry, Université de Montréal, Montreal, Canada

Signals from lower cortical areas are not only transferred directly to higher-order cortical areas via cortico-cortical connections but also indirectly through cortico-thalamo-cortical projections. One step toward the understanding of the role of transthalamic corticocortical pathways is to determine the nature of the signals transmitted between the cortex and the thalamus. Are they strictly modulatory, i.e. are they modifying the activity in relation to the stimulus context and the analysis being done in the projecting area, or are they used to establish basic functional characteristics of cortical cells? While the presence of drivers and modulators has been clearly demonstrated along the retino-geniculo-cortical pathway, it is not known whether such distinction can be made functionally in pathways involving the pulvinar. Since drivers and modulators can exhibit a different temporal pattern of response, we measured the spatiotemporal dynamics of voltage sensitive dyes activation in the visual cortex following pulvinar electrical stimulation in cats and tree shrews. Stimulation of pulvinar induced fast and local responses in extrastriate cortex. In contrast, the propagated waves in the primary visual cortex (V1) were weak in amplitude and diffuse. Co-stimulating pulvinar and LGN produced responses in V1 that were weaker than the sum of the responses evoked by the independent stimulation of both nuclei. These findings support the presence of drivers and modulators along pulvinar pathways and suggest that the pulvinar can exert a modulatory influence in cortical processing of LGN inputs in V1 while it mainly provides driver inputs to extrastriate areas, reflecting the different connectivity patterns.

What is the role of the pulvinar nucleus in visual motion processing?

Heywood M. Petry, Department of Psychological & Brain Sciences, University of Louisville, Martha E. Bickford, Department of Anatomical Sciences and Neurobiology, University of Louisville School of Medicine

To effectively interact with our environment, body movements must be coordinated with the perception of visual movement. We will present evidence that regions of the pulvinar nucleus that receive input from the superior colliculus (tectum) may be involved in this process. We have chosen the tree shrew (Tupaia belangeri, a prototype of early primates), as our animal model because tectopulvinar pathways are particularly enhanced in this species, and our psychophysical experiments have revealed that tree shrews are capable of accurately discriminating small differences in the speed and direction of moving visual displays. Using in vivo electrophysiological recording techniques to test receptive field properties, we found that pulvinar neurons are responsive to moving visual stimuli, and most are direction selective. Using anatomical techniques, we found that tectorecipient pulvinar neurons project to the striatum, amygdala, and temporal cortical areas homologous to the primate middle temporal area, MT/V5. Using in vitro recording techniques, immunohistochemistry and stereology, we found that tectorecipient pulvinar neurons express more calcium channels than other thalamic nuclei and thus display a higher propensity to fire with bursts of action potentials, potentially providing a mechanism to effectively coordinate the activity of cortical and subcortical pulvinar targets. Collectively, these results suggest that the pulvinar nucleus may relay visual movement signals from the superior colliculus to subcortical brain regions to guide body movements, and simultaneously to the temporal cortex to modify visual perception as we move though our environment.

One message the pulvinar sends to cortex

Robert H. Wurtz, NIH-NEI, Lab of Sensorimotor Research, Rebecca Berman, NIH-NEI, Lab of Sensorimotor Research

The pulvinar has long been recognized as a way station on a second visual pathway to the cerebral cortex. This identification has largely been based on the pulvinar's connections, which are appropriate for providing visual information to multiple regions of visual cortex from subcortical areas. What is little known is what information pulvinar actually conveys especially in the intact functioning visual system. We have identified one pathway through the pulvinar that extends from superior colliculus superficial visual layers though inferior pulvinar (principally PIm) to cortical area MT by using the techniques of combined anti- and orthodromic stimulation. We now have explored what this pathway might convey to cortex and have first concentrated on a modulation of visual processing first seen in SC, the suppression of visual responses during saccades. We have been able to replicate the previous observations of the suppression in SC and in MT and now show that PIm neurons also are similarly suppressed. We have then inactivated SC and shown that the suppression in MT is reduced. While we do not know all of the signals conveyed through this pathway to cortex, we do have evidence for one: the suppression of vision during saccades. This signal is neither a visual nor a motor signal but conveys the action of an internal motor signal on visual processing. Furthermore combining our results in the behaving monkey with recent experiments in mouse brain slices (Phongphanphanee et al. 2011) provides a complete circuit from brainstem to cortex for conveying this suppression.

Role of the pulvinar in regulating information transmission between cortical areas

Sabine Kastner, MD, Department of Psychology, Center for Study of Brain, Mind and Behavior, Green Hall, Princeton, Yuri B. Saalman, Princeton Neuroscience Institute, Princeton University

Recent studies suggest that the degree of neural synchrony between cortical areas can modulate their information transfer according to attentional needs. However, it is not clear how two cortical areas synchronize their activities. Directly connected cortical areas are generally also indirectly connected via the thalamic nucleus, the pulvinar. We hypothesized that the pulvinar helps synchronize activity between cortical areas, and tested this by simultaneously recording from the pulvinar, V4, TEO and LIP of macaque monkeys performing a spatial attention task. Electrodes targeted interconnected sites between these areas, as determined by probabilistic tractography on diffusion tensor imaging data. Spatial attention increased synchrony between the cortical areas in the beta frequency range, in line with increased causal influence of the pulvinar on the cortex at the same frequencies. These results suggest that the pulvinar co-ordinates activity between cortical areas, to increase the efficacy of cortico-cortical transmission.

Visual Attention Gates Spatial Coding in the Human Pulvinar

David Whitney, The University of California, Berkeley, Jason Fischer, The University of California, Berkeley

Based on the pulvinar's widespread connectivity with the visual cortex, as well as with putative attentional source regions in the frontal and parietal lobes, the pulvinar is suspected to play an important role in visual attention. However, there remain many hypotheses on the pulvinar's specific function. One hypothesis is that the pulvinar may play a role in filtering distracting stimuli when they are actively ignored. Because it remains unclear whether this is the case, how this might happen, or what the fate of the ignored objects is, we sought to characterize the spatial representation of visual information in the human pulvinar for equally salient attended and ignored objects that were presented simultaneously. In an fMRI experiment, we measured the spatial precision with which attended and ignored stimuli were encoded in the pulvinar, and we found that attention completely gated position information: attended objects were encoded with high spatial precision, but there was no measurable spatial encoding of actively ignored objects. This is despite the fact that the attended and ignored objects were identical and present simultaneously, and both attended and ignored objects were represented with great precision throughout the visual cortex. These data support a role for the pulvinar in distractor filtering and reveal a possible mechanism: by modulating the spatial precision of stimulus encoding, signals from competing stimuli can be suppressed in order to isolate behaviorally relevant objects.

S2

What does fMRI tell us about brain homologies?

Friday, May 11, 1:00 - 3:00 pm, Royal Palm 4-5

Organizer: Reza Rajimehr, McGovern Institute for Brain Research, Massachusetts Institute of Technology

Presenters: Martin Sereno, Department of Cognitive Science, UC San Diego; David Van Essen, Department of Anatomy and Neurobiology, Washington University School of Medicine; Hauke Kolster, Laboratorium voor Neurofysiologie en Psychofysiologie, Katholieke Universiteit Leuven Medical School; Jonathan Winawer, Psychology Department, Stanford University; Reza Rajimehr, McGovern Institute for Brain Research, Massachusetts Institute of Technology

Symposium Summary

Over the past 20 years, the functional magnetic resonance imaging (fMRI) has provided a great deal of knowledge about the functional organization of human visual cortex. In recent years, the development of the fMRI technique in non-human primates has enabled neuroscientists to directly compare visual cortical areas across species. These comparative studies have shown striking similarities ('homologies') between human and monkey visual cortex. Comparing cortical structures in human versus monkey provides a framework for generalizing results from invasive neurobiological studies in monkeys to humans. It also provides important clues for understanding the evolution of cerebral cortex in primates.

Presentations

Evolution, taxonomy, homology, and primate visual areas

Martin Sereno, Department of Cognitive Science, UC San Diego

Evolution involves the repeated branching of lineages, some of which become extinct. The problem of determining the relationship between cortical areas within the brains of surviving branches (e.g., humans, macaques, owl monkeys) is difficult because of: (1) missing evolutionary intermediates, (2) different measurement techniques, (3) body size differences, and (4) duplication, fusion, and reorganization of brain areas. Routine invasive experiments are carried out in very few species (one loris, several New and Old World monkeys). The closest to humans are macaque monkeys. However, the last common ancestor of humans and macaques dates to more than 30 million years ago. Since then, New and Old World monkey brains have evolved independently from ape and human brains, resulting in complex mixes of shared and unique features. Evolutionary biologists are often interested in "shared derived" characters -- specializations from a basal condition that are peculiar to a species or grouping of species. These are important for classification (e.g., a brain feature unique to macaque-like monkeys). Evolutionary biologists also distinguish similarities due to inheritance (homology -- e.g., MT), from similarities due to parallel or convergent evolution (homoplasy -- e.g., layer 4A staining in humans and owl monkey. By contrast with taxonomists, neuroscientists are usually interested in trying to determine which features are conserved across species (whether by inheritance or parallel evolution), indicating that those features may have a basic functional and/or developmental role. The only way to obtain either of these kinds of information is to examine data from multiple species.

Surface-based analyses of human, macaque, and chimpanzee cortical organization

David Van Essen, Department of Anatomy and Neurobiology, Washington University School of Medicine

Human and macaque cortex differ markedly in surface area (nine-fold), in their pattern of convolutions, and in the relationship of cortical areas to these convolutions. Nonetheless, there are numerous similarities and putative homologies in cortical organization revealed by architectonic and other anatomical methods and more recently by noninvasive functional imaging methods. There are also differences in functional organization, particularly in regions of rapid evolutionary expansion in the human lineage. This presentation will highlight recent progress in applying surface-based analysis and visualization methods that provide a powerful general approach for comparisons among primate species, including the macaque, chimpanzee, and human. One major facet involves surface-based atlases that are substrates for increasingly accurate cortical parcellations in each species as well as maps of functional organization revealed using resting-state and task-evoked fMRI. Additional insights into cortical parcellations as well as evolutionary relationships are provided by myelin maps that have been obtained noninvasively in each species. Together, these multiple modalities provide new insights regarding visual cortical organization in each species. Surface-based registration provides a key method for making objective interspecies comparisons, using explicit landmarks that represent known or candidate homologies between areas. Recent algorithmic improvements in landmark-based registration, coupled with refinements in the available set of candidate homologies, provide a fresh perspective on primate cortical evolution and species differences in the pattern of evolutionary expansion.

Comparative mapping of visual areas in the human and macaque occipital cortex

Hauke Kolster, Laboratorium voor Neurofysiologie en Psychofysiologie, Katholieke Universiteit Leuven Medical School

The introduction of functional magnetic resonance imaging (fMRI) as a non-invasive imaging modality has enabled the study of human cortical processes with high spatial specificity and allowed for a direct comparison of the human and the macaque within the same modality. This presentation will focus on the phase-encoded retinotopic mapping technique, which is used to establish parcellations of cortex consisting of distinct visual areas. These parcellations may then be used to test for similarities between the cortical organizations of the two species. Results from ongoing work will be presented with regard to retinotopic organization of the areas as well as their characterizations by functional localizers and population receptive field (pRF) sizes. Recent developments in fMRI methodology, such as improved resolution and stimulus design as well as analytical pRF methods have resulted in higher quality of the retinotopic field maps and revealed visual field-map clusters as new organizational principles in the human and macaque occipital cortex. In addition, measurements of population-average neuronal properties have the potential to establish a direct link between fMRI studies in the human and single cell studies in the monkey. An inter-subject registration algorithm will be presented, which uses a spatial correlation of the retinotopic and the functional test data to directly compare the functional characteristics of a set of putative homologue areas across subjects and species. The results indicate strong similarities between twelve visual areas in occipital cortex of human and macaque in terms of topological organization, functional characteristics and pRF sizes.

The fourth visual area: A question of human and macaque homology

Jonathan Winawer, Psychology Department, Stanford University

The fourth visual area, V4, was identified in rhesus macaque and described in a series of anatomical and functional studies (Zeki 1971, 1978). Because of its critical role in seeing color and form, V4 has remained an area of intense study. The identification of a color-sensitive region on the ventral surface of human visual cortex, anterior to V3, suggested the possible homology between this area, labeled 'Human V4' or 'hV4' (McKeefry, 1997; Wade, 2002) and macaque V4 (mV4). Both areas are retinotopically organized. Homology is not uniformly accepted because of substantial differences in spatial organization, though these differences have been questioned (Hansen, 2007). MV4 is a split hemifield map, with parts adjacent to the ventral and dorsal portions of the V3 map. In contrast, some groups have reported that hV4 falls wholly on ventral occipital cortex. Over the last 20 years, several organizational schemes have been proposed for hV4 and surrounding maps. In this presentation I review evidence for the different schemes, with emphasis on recent findings showing that an artifact of functional MRI caused by the transverse sinus afflicts measurements of the hV4 map in many (but not all) hemispheres. By focusing on subjects where the hV4 map is relatively remote from the sinus artifact, we show that hV4 can be best described as a single, unbroken map on the ventral surface representing the full contralateral visual hemifield. These results support claims of substantial deviations from homology between human and macaque in the organization of the 4th visual map.

Spatial organization of face and scene areas in human and macaque visual cortex

Reza Rajimehr, McGovern Institute for Brain Research, Massachusetts Institute of Technology

The primate visual cortex has a specialized architecture for processing specific object categories such as faces and scenes. For instance, inferior temporal cortex in macaque contains a network of discrete patches for processing face images. Direct comparison between human and macaque category-selective areas shows that some areas in one species have missing homologues in the other species. Using fMRI, we identified a face-selective region in anterior temporal cortex in human and a scene-selective region in posterior temporal cortex in macaque, which correspond to homologous areas in the other species. A surface-based analysis of cortical maps showed a high degree of similarity in the spatial arrangement of face and scene areas between human and macaque. This suggests that neighborhood relations between functionally-defined cortical areas are evolutionarily conserved - though the topographic relation between the areas and their underlying anatomy (gyral/sulcal pattern) may vary from one species to another.

S3
Part-whole relationships in visual cortex

Friday, May 11, 1:00 - 3:00 pm, Royal Palm 6-8

Organizer: Johan Wagemans, Laboratory of Experimental Psychology, University of Leuven

Presenters: Johan Wagemans, Laboratory of Experimental Psychology, University of Leuven; Charles E. Connor, Department of Neuroscience and Zanvyl Krieger Mind/Brain Institute, Johns Hopkins University; Scott O. Murray, Department of Psychology, University of Washington; James R. Pomerantz, Department of Psychology, Rice University; Jacob Feldman,Dept. of Psychology, Center for Cognitive Science, Rutgers University - New Brunswick; Shaul Hochstein, Departments of Neurobiology and Psychology, Hebrew University

Symposium Summary

In 1912 Wertheimer launched Gestalt psychology, arguing that the whole is different from the sum of the parts. Wholes were considered primary in perceptual experience, even determining what the parts are. How to reconcile this position with what we now know about the visual brain, in terms of a hierarchy of processing layers from low-level features to integrated object representations at the higher level? What exactly are the relationships between parts and wholes then? A century later, we will take stock and provide an answer from a diversity of approaches, including single-cell recordings, human fMRI, human psychophysics, and computational modeling.

Presentations

Part-whole relationships in vision science: A brief historical review and conceptual analysis

Johan Wagemans, Laboratory of Experimental Psychology, University of Leuven

Exactly 100 years ago, Wertheimer's paper on phi motion (1912) effectively launched the Berlin school of Gestalt psychology. Arguing against elementalism and associationism, they maintained that experienced objects and relationships are fundamentally different from collections of sensations. Going beyond von Ehrenfels's notion of Gestalt qualities, which involved one-sided dependence on sense data, true Gestalts are dynamic structures in experience that determine what will be wholes and parts. From the beginning, this two-sided dependence between parts and wholes was believed to have a neural basis. They spoke of continuous "whole-processes" in the brain, and argued that research needed to try to understand these from top (whole) to bottom (parts) rather than the other way around. However, Gestalt claims about global precedence and configural superiority are difficult to reconcile with what we now know about the visual brain, with a hierarchy from lower areas processing smaller parts of the visual field and higher areas responding to combinations of these parts in ways that are gradually more invariant to low-level changes to the input and corresponding more closely to perceptual experience. What exactly are the relationships between parts and wholes then? In this talk, I will briefly review the Gestalt position and analyse the different notions of part and whole, and different views on part-whole relationships maintained in a century of vision science since the start of Gestalt psychology. This will provide some necessary background for the remaining talks in this symposium, which will all present contemporary views based on new findings.

Ventral pathway visual cortex: Representation by parts in a whole object reference frame

Charles E. Connor, Department of Neuroscience and Zanvyl Krieger Mind/Brain Institute, Johns Hopkins University, Anitha Pasupathy, Scott L. Brincat, Yukako Yamane, Chia-Chun Hung

Object perception by humans and other primates depends on the ventral pathway of visual cortex, which processes information about object structure, color, texture, and identity. Object information processing can be studied at the algorithmic, neural coding level using electrode recording in macaque monkeys. We have studied information processing in three successive stages of the monkey ventral pathway: area V4, PIT (posterior inferotemporal cortex), and AIT (anterior inferotemporal cortex). At all three stages, object structure is encoded in terms of parts, including boundary fragments (2D contours, 3D surfaces) and medial axis components (skeletal shape fragments). Area V4 neurons integrate information about multiple orientations to produce signals for local contour fragments. PIT neurons integrate multiple V4 inputs to produce representations of multi-fragment configurations. Even neurons in AIT, the final stage of the monkey ventral pathway, represent configurations of parts (as opposed to holistic object structure). However, at each processing stage, neural responses are critically dependent on the position of parts within the whole object. Thus, a given neuron may respond strongly to a specific contour fragment positioned near the right side of an object but not at all when it is positioned near the left. This kind of object-centered position tuning would serve an essential role by representing spatial arrangement within a distributed, parts-based coding scheme. Object-centered position sensitivity is not imposed by top-down feedback, since it is apparent in the earliest responses at lower stages, before activity begins at higher stages. Thus, while the brain encodes objects in terms of their constituent parts, the relationship of those parts to the whole object is critical at each stage of ventral pathway processing.

Long-range, pattern-dependent contextual effects in early human visual cortex

Scott O. Murray, Department of Psychology, University of Washington, Sung Jun Joo, Geoffrey M. Boynton

The standard view of neurons in early visual cortex is that they behave like localized feature detectors. We will discuss recent results that demonstrate that neurons in early visual areas go beyond localized feature detection and are sensitive to part-whole relationships in images. We measured neural responses to a grating stimulus (“target”) embedded in various visual patterns as defined by the relative orientation of flanking stimuli. We varied whether or not the target was part of a predictable sequence by changing the orientation of distant gratings while maintaining the same local stimulus arrangement. For example, a vertically oriented target grating that is flanked locally with horizontal flankers (HVH) can be made to be part of a predictable sequence by adding vertical distant flankers (VHVHV). We found that even when the local configuration (e.g. HVH) around the target was kept the same there was a smaller neural response when the target was part of a predictable sequence (VHVHV). Furthermore, when making an orientation judgment of a “noise” stimulus that contains no specific orientation information, observers were biased to “see” the orientation that deviates from the predictable orientation, consistent with computational models of primate cortical processing that incorporate efficient coding principles. Our results suggest that early visual cortex is sensitive to global patterns in images in a way that is markedly different from the predictions of standard models of cortical visual processing and indicate an important role in coding part-whole relationships in images.

The computational and cortical bases for configural superiority

James R. Pomerantz, Department of Psychology, Rice University, Anna I. Cragin, Department of Psychology, Rice University; Kimberley D. Orsten, Department of Psychology, Rice University; Mary C. Portillo, Department of Social Sciences, University of Houston–Downtown

In the configural superiority effect (CSE; Pomerantz et al., 1977; Pomerantz & Portillo, 2011), people respond more quickly to a whole configuration than to any one of its component parts, even when the parts added to create a whole contribute no information by themselves. For example, people discriminate an arrow from a triangle more quickly than a positive from a negative diagonal even when those diagonals constitute the only difference between the arrows and triangles. How can a neural or other computational system be faster at processing information about combinations of parts – wholes – than about parts taken singly? We consider the results of Kubilius et al. (2011) and discuss three possibilities: (1) Direct detection of wholes through smart mechanisms that compute higher order information without performing seemingly necessary intermediate computations; (2) the “sealed channel hypothesis” (Pomerantz, 1978), which holds that part information is extracted prior to whole information in a feedforward manner but is not available for responses; and (3) a closely related reverse hierarchy model holding that conscious experience begins with higher cortical levels processing wholes, with parts becoming accessible to consciousness only after feedback to lower levels is complete (Hochstein & Ahissar, 2002). We describe a number of CSEs and elaborate both on these mechanisms that might explain them and how they might be confirmed experimentally.

Computational integration of local and global form

Jacob Feldman, Dept. of Psychology, Center for Cognitive Science, Rutgers University - New Brunswick, Manish Singh, Vicky Froyen

A central theme of perceptual theory, from the Gestaltists to the present, has been the integration of local and global image information. While neuroscience has traditionally viewed perceptual processes as beginning with local operators with small receptive fields before proceeding on to more global operators with larger ones, a substantial body of evidence now suggests that supposedly later processes can impose decisive influences on supposedly earlier ones, suggesting a more complicated flow of information. We consider this problem from a computational point of view. Some local processes in perceptual organization, like the organization of visual items into a local contour, can be well understood in terms of simple probabilistic inference models. But for a variety of reasons nonlocal factors such as global “form” resist such simple models. In this talk I’ll discuss constraints on how form- and region-generating probabilistic models can be formulated and integrated with local ones. From a computational point of view, the central challenge is how to embed the corresponding estimation procedure in a locally-connected network-like architecture that can be understood as a model of neural computation.

The rise and fall of the Gestalt gist

Shaul Hochstein, Departments of Neurobiology and Psychology, Hebrew University, Merav Ahissar

Reviewing the current literature, one finds physiological bases for Gestalt-like perception, but also much that seems to contradict the predictions of this theory. Some resolution may be found in the framework of Reverse Hierarchy Theory, dividing between implicit processes, of which we are unaware, and explicit representations, which enter perceptual consciousness. It is the conscious percepts that appear to match Gestalt predictions – recognizing wholes even before the parts. We now need to study the processing mechanisms at each level, and, importantly, the feedback interactions which equally affect and determine the plethora of representations that are formed, and to analyze how they determine conscious perception. Reverse Hierarchy Theory proposes that initial perception of the gist of a scene – including whole objects, categories and concepts – depends on rapid bottom-up implicit processes, which seems to follow (determine) Gestalt rules. Since lower level representations are initially unavailable to consciousness – and may become available only with top-down guidance – perception seems to immediately jump to Gestalt conclusions. Nevertheless, vision at a blink of the eye is the result of many layers of processing, though introspection is blind to these steps, failing to see the trees within the forest. Later, slower perception, focusing on specific details, reveals the source of Gestalt processes – and destroys them at the same time. Details of recent results, including micro-genesis analyses, will be reviewed within the framework of Gestalt and Reverse Hierarchy theories.

S4

Distinguishing perceptual shifts from response biases

Friday, May 11, 3:30 - 5:30 pm, Royal Palm 1-3

Organizer: Joshua Solomon, City University London

Presenters: Sam Ling, Vanderbilt; Keith Schneider, York University; Steven Hillyard, UCSD; Donald MacLeod, UCSD; Michael Morgan, City University London, Max Planck Institute for Neurological Research, Cologne; Mark Georgeson, Aston University

Symposium Summary

Our general topic will be the measurement of perceptual biases. These are changes in appearance that cannot be attributed to changes in the visual stimulus. One perceptual bias that has received a lot of attention lately is the change in apparent contrast that observers report when they attend (or remove attention from) a visual target. We will discuss how to distinguish reports of truly perceptual changes from changes in response strategies.

Presentations

Attention alters appearance

Sam Ling, Vanderbilt University

Maintaining veridicality seems to be of relatively low priority for the human brain; starting at the retina, our neural representations of the physical world undergo dramatic transformations, often forgoing an accurate depiction of the world in favor of augmented signals that are more optimal for the task at hand. Indeed, visual attention has been suggested to play a key role in this process, boosting the neural representations of attended stimuli, and attenuating responses to ignored stimuli. What, however, are the phenomenological consequences of attentional modulation? I will discuss a series of studies that we and others have conducted, all converging on the notion that attention can actually change the visual appearance of attended stimuli across a variety of perceptual domains, such as contrast, spatial frequency, and color. These studies reveal that visual attention not only changes our neural representations, but that it can actually affect what we think we see.

Attention increases salience and biases decisions but does not alter appearance.

Keith Schneider, York University

Attention enhances our perceptual abilities and increases neural activity. Still debated is whether an attended object, given its higher salience and more robust representation, actually looks any different than an otherwise identical but unattended object. One might expect that this question could be easily answered by an experiment in which an observer is presented two stimuli differing along one dimension, contrast for example, to one of which attention has been directed, and must report which stimulus has the higher apparent contrast. The problem with this sort of comparative judgment is that in the most informative case, that in which the two stimuli are equal, the observer is also maximally uncertain and therefore most susceptible to extraneous influence. An intelligent observer might report, all other things being equal, that the stimulus about which he or she has more information is the one with higher contrast. (And it doesn't help to ask which stimulus has the lower contrast, because then the observer might just report the less informed stimulus!) In this way, attention can bias the decision mechanism and confound the experiment such that it is not possible for the experimenter to differentiate this bias from an actual change in appearance. It has been over ten years since I proposed a solution to this dilemma—an equality judgment task in which observers report whether the two stimuli are equal in appearance or not. This paradigm has been supported in the literature and has withstood criticisms. Here I will review these findings.

Electrophysiological Studies of the Locus of Perceptual Bias

Steven Hillyard, UCSD

The question of whether attention makes sensory impressions appear more intense has been a matter of debate for over a century. Recent psychophysical studies have reported that attention increases the apparent contrast of visual stimuli, but there is still a controversy as to whether this effect is due to the biasing of decisions as opposed to the altering of perceptual representations and changes in subjective appearance. We obtained converging neurophysiological evidence while observers judged the relative contrast of Gabor patch targets presented simultaneously to the left and right visual fields following a lateralized cue (auditory or visual). This non-predictive cueing boosted the apparent contrast of the Gabor target on the cued side in association with an enlarged neural response in the contralateral visual cortex that began within 100 ms after target onset. The magnitude of the enhanced neural response in ventral extrastriate visual cortex was positively correlated with perceptual reports of the cued-side target being higher in contrast. These results suggest that attention increases the perceived contrast of visual stimuli by boosting early sensory processing in the visual cortex.

Adaptive sensitivity regulation in detection and appearance

Donald MacLeod, UCSD

The visual system adapts to changing levels of stimulation with alterations of sensitivity that are expressed both in in changes in detectability, and in changes of appearance. The connection between these two aspects of sensitivity regulation is often taken for granted but need not be simple. Even the proportionality between 'thresholds' obtained by self-setting and threshold based on reliability of detection (e.g. forced-choice) is not generally expected except under quite restricted conditions and unrealistically simple models of the visual system. I review some of the theoretical possibilities in relation to available experimental evidence. Relatively simple mechanistic models provide opportunity for deviations from proportionality, especially if noise can enter into the neural representation at multiple stages. The extension to suprathreshold appearance is still more precarious; yet remarkably, under some experimental conditions, proportionality with threshold sensitivities holds, in the sense that equal multiples of threshold match.

Observers can voluntarily shift their psychometric functions without losing sensitivity

Michael Morgan, City University London, Max Planck Institute for Neurological Research, Cologne, Barbara Dillenburger, Sabine Raphael, Max Planck; Joshua A. Solomon, City University

Psychometric sensory discrimination functions are usually modeled by cumulative Gaussian functions with just two parameters, their central tendency and their slope. These correspond to Fechner's "constant" and "variable" errors, respectively. Fechner pointed out that even the constant error could vary over space and time and could masquerade as variable error. We wondered whether observers could deliberately introduce a constant error into their performance without loss of precision. In three-dot vernier and bisection tasks with the method of single stimuli, observers were instructed to favour one of the two responses when unsure of their answer. The slope of the resulting psychometric function was not significantly changed, despite a significant change in central tendency. Similar results were obtained when altered feedback was used to induce bias. We inferred that observers can adopt artificial response criteria without any significant increase in criterion fluctuation. These findings have implications for some studies that have measured perceptual "illusions" by shifts in the psychometric functions of sophisticated observers.

Sensory, perceptual and response biases: the criterion concept in perception

Mark Georgeson, Aston University

Signal detection theory (SDT) established in psychophysics a crucial distinction between sensitivity (or discriminability, d') and bias (or criterion) in the analysis of performance in sensory judgement tasks. SDT itself is agnostic about the origins of the criterion, but there seems to be a broad consensus favouring 'response bias' or 'decision bias'. And yet, perceptual biases exist and are readily induced. The motion aftereffect is undoubtedly perceptual - compelling motion is seen on a stationary pattern – but its signature in psychophysical data is a shift in the psychometric function, indistinguishable from 'response bias'. How might we tell the difference? I shall discuss these issues in relation to some recent experiments and modelling of adaptation to blur (Elliott, Georgeson & Webster, 2011). A solution might lie in dropping any hard distinction between perceptual shifts and decision biases. Perceptual mechanisms make low-level decisions. Sensory, perceptual and response criteria might be represented neurally in similar ways at different levels of the visual hierarchy, by biasing signals that are set by the task and by the history of stimuli and responses (Treisman & Williams, 1984). The degree of spatial localization over which the bias occurs might reflect its level in the visual hierarchy. Thus, given enough data, the dilemma (are aftereffects perceptual or due to response bias?) might be resolved in favour of such a multi-level model.

S5

Human visual cortex: from receptive fields to maps to clusters to perception

Friday, May 11, 3:30 - 5:30 pm, Royal Palm 4-5

Organizer: Serge O. Dumoulin, Experimental Psychology, Helmholtz Institute, Utrecht University, Netherlands

Presenters: Serge O. Dumoulin, Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, Netherlands; Koen V. Haak,Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, Groningen, Netherlands.; Alex R. Wade, Department of Psychology University of York, Heslington, UK; Mark M. Schira, Neuroscience Research Australia (NeuRA), Sydney & University of New South Wales, Sydney, Australia; Stelios M. Smirnakis,Departments of Neurosci. and Neurol., Baylor Col. of Med., Houston, TX; Alyssa A. Brewer, Department of Cognitive Sciences University of California, Irvine

Symposium Summary

This symposium will introduce current concepts of the visual cortex' organization at different spatial scales and their relation to perception. At the smallest scale, the receptive field is a property of individual neurons and summarizes the visual field region where visual stimulation elicits a response. These receptive fields are organized into visual field maps, which in turn are organized in clusters that share a common fovea. We will relate these principles to notions of population receptive fields (pRF), cortico-cortical pRFs, extra-classical contextual effects, detailed foveal organization, visual deprivation, prism-adaptation and plasticity.

Presentations

Reconstructing human population receptive field properties

Serge O. Dumoulin, Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, Netherlands, B.M. Harvey, Experimental Psychology, Utrecht University, Netherlands

We describe a method that reconstructs population receptive field (pRF) properties in human visual cortex using fMRI. This data-analysis technique is able to reconstruct several properties of the underlying neural population, such as quantitative estimates of the pRF position (maps), size as well as suppressive surrounds. PRF sizes increase with increasing eccentricity and up the visual hierarchy. In the same human subject, fMRI pRF measurements are comparable to those derived from subdural electrocorticography (ECoG). Furthermore, we describe a close relationship of pRF sizes to the cortical magnification factor (CMF). Within V1, interhemisphere and subject variations in CMF, pRF size, and V1 surface area are correlated. This suggests a constant processing unit shared between humans. PRF sizes increase between visual areas and with eccentricity, but when expressed in V1 cortical surface area (i.e., cortico-cortical pRFs), they are constant across eccentricity in V2 and V3. Thus, V2, V3, and to some degree hV4, sample from a constant extent of V1. This underscores the importance of V1 architecture as a reference frame for subsequent processing stages and ultimately perception.

Cortico-cortical receptive field modeling using functional magnetic resonance imaging (fMRI)

Koen V. Haak, Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, Groningen, Netherlands, J. Winawer, Psychology, Stanford University; B.M. Harvey, Experimental Psychology, Utrecht University; R. Renken, Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, Netherlands; S.O. Dumoulin, Experimental Psychology, Utrecht University, Netherlands; B.A. Wandell, Psychology, Stanford University; F.W. Cornelissen, Laboratory for Experimental Ophthalmology, University Medical Center Groningen, University of Groningen, Netherlands

The traditional way to study the properties of cortical visual neurons is to measure responses to visually presented stimuli (stimulus-referred). A second way to understand neuronal computations is to characterize responses in terms of the responses in other parts of the nervous system (neural-referred). A model that describes the relationship between responses in distinct cortical locations is essential to clarify the network of cortical signaling pathways. Just as a stimulus-referred receptive field predicts the neural response as a function of the stimulus contrast, the neural-referred receptive field predicts the neural response as a function of responses elsewhere in the nervous system. When applied to two cortical regions, this function can be called the population cortico-cortical receptive field (CCRF), and it can be used to assess the fine-grained topographic connectivity between early visual areas. Here, we model the CCRF as a Gaussian-weighted region on the cortical surface and apply the model to fMRI data from both stimulus-driven and resting-state experimental conditions in visual cortex to demonstrate that 1) higher order visual areas such as V2, V3, hV4 and the LOC show an increase in the CCRF size when sampling from the V1 surface, 2) the CCRF size of these higher order visual areas is constant over the V1 surface, 3) the method traces inherent properties of the visual cortical organization, 4) it probes the direction of the flow of information.

Imaging extraclassical receptive fields in early visual cortex

Alex R. Wade, Department of Psychology University of York, Heslington, UK, B. Xiao, Department of Brain and Cognitive Sciences, MIT; J. Rowland, Department of Art Practise, UC Berkeley

Psychophysically, apparent color and contrast can be modulated by long-range contextual effects. In this talk I will describe a series of neuroimaging experiments that we have performed to examine the effects of spatial context on color and contrast signals in early human visual cortex. Using fMRI we first show that regions of high contrast in the fovea exert a long-range suppressive effect across visual cortex that is consistent with a contrast gain control mechanism. This suppression is weaker when using stimuli that excite the chromatic pathways and may occur relatively early in the visual processing stream (Wade, Rowland, J Neurosci, 2010). We then used high-resolution source imaged EEG to examine the effects of context on V1 signals initiated in different chromatic and achromatic precortical pathways (Xiao and Wade, J Vision, 2010). We found that contextual effects similar to those seen in classical psychophysical 'surround suppression' were present in both S-cone and achromatic pathways but that there was little contextual interaction between these pathways - either in our behavioral or in our neuroimaging paradigms. Finally, we used fMRI multivariate pattern analysis techniques to examine the presence of chromatic tuning in large extraclassical receptive fields (ECRFs). We found that ECRFs have sufficient chromatic tuning to enable classification based solely on information in suppressed voxels that are not directly excited by the stimulus. In many cases, performance using ECRFs was as accurate as that using voxels driven directly by the stimulus.

The human foveal confluence and high resolution fMRI

Mark M. Schira, Neuroscience Research Australia (NeuRA), Sydney & University of New South Wales, Sydney, Australia

After remaining terra incognita for 40 years, the detailed organization of the foveal confluence has just recently been described in humans. I will present recent high resolution mapping results in human subjects and introduce current concepts of its organization in human and other primates (Schira et al., J. Nsci, 2009). I will then introduce a new algebraic retino-cortical projection function that accurately models the V1-V3 complex to the level of our knowledge about the actual organization (Schira et al. PLoS Comp. Biol. 2010). Informed by this model I will discuss important properties of foveal cortex in primates. These considerations demonstrate that the observed organization though surprising at first hand is in fact a good compromise with respect to cortical surface and local isotropy, proving a potential explanation for this organization. Finally, I will discuss recent advances such as multi-channel head coils and parallel imaging which have greatly improved the quality and possibilities of MRI. Unfortunately, most fMRI research is still essentially performed in the same old 3 by 3 by 3 mm style - which was adequate when using a 1.5T scanner and a birdcage head coil. I will introduce simple high resolution techniques that allow fairly accurate estimates of the foveal organization in research subjects within a reasonable timeframe of approximately 20 minutes, providing a powerful tool for research of foveal vision.

Population receptive field measurements in macaque visual cortex

Stelios M. Smirnakis, Departments of Neurosci. and Neurol., Baylor Col. of Med., Houston, TX, G.A. Keliris, Max Planck Inst. For Biol. Cybernetics, Tuebingen, Germany; Y. Shao, A. Papanikolaou, Max Planck Inst. For Biol. Cybernetics, Tuebingen, Germany; N.K. Logothetis, Max Planck Inst. For Biol. Cybernetics, Tuebingen, Germany, Div. of Imaging Sci. and Biomed. Engin., Univ. of Manchester, United Kingdom

Visual receptive fields have dynamic properties that may change with the conditions of visual stimulation or with the state of chronic visual deprivation. We used 4.7 Tesla functional magnetic resonance imaging (fMRI) to study the visual cortex of two normal adult macaque monkeys and one macaque with binocular central retinal lesions due to a form of juvenile macular degeneration (MD). FMRI experiments were performed under light remifentanyl induced anesthesia (Logothetis et al. Nat. Neurosci. 1999). Standard moving horizontal/vertical bar stimuli were presented to the subjects and the population receptive field (pRF) method (Dumoulin and Wandell, Neuroimage 2008) was used to measure retinotopic maps and pRF sizes in early visual areas. FMRI measurements of normal monkeys agree with published electrophysiological results, with pRF sizes and electrophysiology measurements showing similar trends. For the MD monkey, the size and location of the lesion projection zone (LPZ) was consistent with the retinotopic projection of the retinal lesion in early visual areas. No significant BOLD activity was seen within the V1 LPZ, and the retinotopic organization of the non-deafferented V1 periphery was regular without distortion. Interestingly, area V5/MT of the MD monkey showed more extensive activation than area V5/MT of control monkeys which had part of their visual field obscured (artificial scotoma) to match the scotoma of the MD monkey. V5/MT PRF sizes of the MD monkey were on average smaller than controls. PRF estimation methods allow us to measure and follow in vivo how the properties of visual areas change as a function of cortical reorganization. Finally, if there is time, we will discuss a different method of pRF estimation that yields additional information.

Functional plasticity in human parietal visual field map clusters: Adapting to reversed visual input

Alyssa A. Brewer, Department of Cognitive Sciences University of California, Irvine Irvine, CA, B. Barton, Department of Cognitive Sciences University of California, Irvine; L. Lin, AcuFocus, Inc., Irvine

Knowledge of the normal organization of visual field map clusters allows us to study potential reorganization within visual cortex under conditions that lead to a disruption of the normal visual inputs. Here we exploit the dynamic nature of visuomotor regions in posterior parietal cortex to examine cortical functional plasticity induced by a complete reversal of visual input in normal adult humans. We also investigate whether there is a difference in the timing or degree of a second adaptation to the left-right visual field reversal in adult humans after long-term recovery from the initial adaptation period. Subjects wore left-right reversing prism spectacles continuously for 14 days and then returned for a 4-day re-adaptation to the reversed visual field 1-9 months later. For each subject, we used population receptive field modeling fMRI methods to track the receptive field alterations within the occipital and parietal visual field map clusters across time points. The results from the first 14-day experimental period highlight a systematic and gradual shift of visual field coverage from contralateral space into ipsilateral space in parietal cortex throughout the prism adaptation period. After the second, 4-day experimental period, the data demonstrate a faster time course for both behavioral and cortical re-adaptation. These measurements in subjects with severely altered visual input allow us to identify the cortical regions subserving the dynamic remapping of cortical representations in response to altered visual perception and demonstrate that the changes in the maps produced by the initial long prism adaptation period persist over an extended time.

S6

Neuromodulation of Visual Perception

Friday, May 11, 3:30 - 5:30 pm, Royal Palm 6-8

Organizers: Jutta Billino, Justus-Liebig-University Giessen and Ulrich Ettinger, Rheinische Friedrich-Wilhelms-Universität Bonn

Presenters: Anita A. Disney, Salk Institute; Alexander Thiele, Institute of Neuroscience, Newcastle University, Newcastle Upon Tyne, United Kingdom; Behrad Noudoost, Department of Neurobiology, Stanford University School of Medicine; Ariel Rokem, Department of Psychology, Stanford University; Ulrich Ettinger, Rheinische Friedrich-Wilhelms-Universität Bonn; Patrick J. Bennett, Department of Psychology, Neuroscience & Behaviour McMaster University

Symposium Summary

Although the neuronal bases of vision have been extensively explored over the last decades we are just beginning to understand how visual perception is modulated by neurochemical processes in our brain. Recent research provides first insights into regulation of signal processing by different neurotransmitters. This symposium is devoted to the questions (1) by which mechanisms neurotransmitters influence perception and (2) how individual differences in neurotransmitter activity could explain normal variation and altered visual processing in mental disease and during ageing. Presentations will provide an overview of state-of-the-art methods and findings concerning the complexity of neuromodulation of visual perception.

Presentations

Modulating visual gain: cholinergic mechanisms in macaque V1

Anita A. Disney, Salk Institute, Michael J. Hawken, Center for Neural Science, New York University

Cholinergic neuromodulation has been suggested to underlie arousal and attention in mammals. Acetylcholine (ACh) is released in cortex by volume transmission and so specificity in its effects must largely be conferred by selective expression of ACh receptors (AChRs). To dissect the local circuit action of ACh, we have used both quantitative anatomy and in vivo physiology and pharmacology during visual stimulation in macaque primary visual cortex (V1). We have shown that nicotinic AChRs are found presynaptically at thalamocortical synapses arriving at spiny neurons in layer 4c of V1 and that nicotine acts in this layer to enhance the gain of visual neurons. Similar evidence for nicotinic enhancement of thalamocortical transmission has been found in the primary cortices of other species and across sensory systems. In separate experiments we have shown that, amongst intrinsic V1 neurons, a higher proportion of GABAergic – in particular parvalbumin-immunoreactive - neurons express muscarinic AChRs than do excitatory neurons. We have also shown that ACh strongly suppresses visual responses outside layer 4c of macaque V1 and that this suppression can be blocked using a GABAa receptor antagonist. Suppression by ACh has been demonstrated in other cortical model systems but is often found to be mediated by reduced glutamate release rather than enhanced release of GABA. Recent anatomical data on AChR expression in the extrastriate visual cortex of the macaque and in V1 of rats, ferrets, and humans, suggest that there may be variation in the targeting of muscarinic mechanisms across neocortical model systems

Differential contribution of cholinergic and glutamatergic receptors to attentional modulation in V1

Alexander Thiele, Institute of Neuroscience, Newcastle University, Newcastle Upon Tyne, United Kingdom, Jose Herreo, Institute of Neuroscience, Newcastle University, Newcastle Upon Tyne, United Kingdom; Alwin Gieselmann, Institute of Neuroscience, Newcastle University, Newcastle Upon Tyne, United Kingdom

In V1, attentional modulation of firing rates is dependent on cholinergic (muscarinic) mechanisms (Herrero et al., 2008). Modelling suggests that appropriate ACh drive enables top-down feedback from higher cortical areas to exert its influence (Deco & Thiele, 2011). The implementation of such feedback at the transmitter/receptor level is poorly understood, but it is generally assumed that feedback relies on ionotropic glutamatergic (iGluR) mechanisms. We investigated this possibility by combining iontophoretic pharmacological analysis with V1 cell recordings while macaques performed a spatial attention task. Blockade or activation of iGluR did not alter attention-induced increases in firing rate, when compared to attend away conditions. However, attention reduced firing rate variance as previously reported in V4 (Mitchell, Sundberg, Reynolds, 2007), and this reduction depended on functioning iGluRs. Attention also reduced spike coherence between simultaneously recorded neurons in V1 as previously demonstrated for V4 (Cohen & Maunsell, 2009; Mitchell et al., 2007). Again, this reduction depended on functional iGluR. Thus overall excitatory drive (probably aided by feedback), increased the signal to noise ratio (reduced firing rate variance) and reduced redundancy of information transmission (noise correlation) in V1. Conversely, attention induced firing rate differences are enabled by the cholinergic system. These studies identify independent contributions of different neurotransmitter systems to attentional modulation in V1.

Dopamine-mediated prefrontal control of visual cortical signals

Behrad Noudoost, Department of Neurobiology, Stanford University School of Medicine, Tirin Moore, Department of Neurobiology, Stanford University School of Medicine & Howard Hughes Medical Institute, Stanford University School of Medicine

Prefrontal cortex (PFC) is believed to play a crucial role in executive control of cognitive functions. Part of this control is thought to be achieved by control of sensory signals in posterior sensory cortices. Dopamine is known to play a role in modulating the strength of signals within the PFC. We tested whether this neurotransmitter is involved in PFC's top-down control of signals within posterior sensory areas. We recorded responses of neurons in visual cortex (area V4) before and after infusion of the D1 receptor (D1R)-antagonist SCH23390 into the frontal eye field (FEF) in monkeys performing visual fixation and saccadic target selection tasks. Visual stimuli were presented within the shared response fields of simultaneously studied V4 and FEF sites. We found that modulation of D1R-mediated activity within the FEF enhances the strength of visual signals in V4 and increases the monkeys' tendency to choose targets presented within the affected part of visual space. Similar to the D1R manipulation, modulation of D2R-mediated activity within the FEF also increased saccadic target selection. However, it failed to alter visual responses within area V4. The observed effects of D1Rs in mediating the control of visual cortical signals and the selection of visual targets, coupled with its known role in working memory, suggest PFC dopamine as a key player in the control of cognitive functions.

Cholinergic enhancement of perceptual learning in the human visual system

Ariel Rokem, Department of Psychology, Stanford University, Michael A. Silver, Helen Wills Neuroscience Institute and School of Optometry, University of California, Berkeley

Learning from experience underlies our ability to adapt to novel tasks and unfamiliar environments. But how does the visual system know when to adapt and change and when to remain stable? The neurotransmitter acetylcholine (ACh) has been shown to play a critical role in cognitive processes such as attention and learning. Previous research in animal models has shown that plasticity in sensory systems often depends on the task relevance of the stimulus, but experimentally increasing ACh in cortex can replace task relevance in inducing experience-dependent plasticity. Perceptual learning (PL) is a specific and persistent improvement in performance of a perceptual task with training. To test the role of ACh in PL of visual discrimination, we pharmacologically enhanced cholinergic transmission in the brains of healthy human participants by administering the cholinesterase inhibitor donepezil (trade name: Aricept), a commonly prescribed treatment for Alzheimer's disease. To directly evaluate the effect of cholinergic enhancement, we conducted a double-blind, placebo-controlled crossover study, in which each subject participated in a course of training under placebo and a course of training under donepezil. We found that, relative to placebo, donepezil increased the magnitude and specificity of the improvement in perceptual performance following PL. These results suggest that ACh plays a role in highlighting occasions in which learning should occur. Specifically, ACh may regulate neural plasticity by selectively increasing responses of neurons to behaviorally relevant stimuli.

Pharmacological Influences on Oculomotor Control in Healthy Humans

Ulrich Ettinger, Rheinische Friedrich-Wilhelms-Universität Bonn

Oculomotor control can be studied as an important model system for our understanding of how the brain implements visually informed (reflexive and voluntary) movements. A number of paradigms have been developed to investigate specific aspects of the cognitive and sensorimotor processes underlying this fascinating ability of the brain. For example, saccadic paradigms allow the specific and experimentally controlled study of response inhibition as well as temporo-spatial prediction. In this talk I will present recent data from studies investigating pharmacological influences on saccadic control in healthy humans. Findings from nicotine studies point to improvements of response inhibition and volitional response generation through this cholinergic agonist. Evidence from methylphenidate on the other hand suggests that oculomotor as well as motor response inhibition is unaffected by this dopaminergic manipulation, whereas the generation of saccades to temporally predictive visual targets is improved. These findings will be integrated with our published and ongoing work on the molecular genetic correlates of eye movements as well as their underlying brain activity. I will conclude by (1) summarising the pharmacological mechanisms underlying saccadic control and (2) emphasising the role that such oculomotor tasks may play in the evaluation of potential cognitive enhancing compounds, with implications for neuropsychiatric conditions such as ADHD, schizophrenia and dementia.

The effects of aging on GABAergic mechanisms and their influence on visual perception

Patrick J. Bennett and Allison B. Sekuler, Department of Psychology, Neuroscience & Behaviour McMaster University

The functional properties of visual mechanisms, such as the tuning properties of visual cortical neurons, are thought to emerge from an interaction among excitatory and inhibitory neural mechanisms. Hence, changing the balance between excitation and inhibition should lead, at least in some cases, to measurable changes in these mechanisms and, presumably, visual perception. Recent evidence suggests that aging is associated with changes in GABAergic signaling (Leventhal et al., 2003; Pinto et al., 2010), however it remains unclear how these changes manifest themselves in performance in psychophysical tasks. Specifically, some psychophysical studies (Betts et al., 2005; Wilson et al., 2011), but not all, are consistent with the idea that certain aspects of age-related changes in vision are caused by a reduction in the effectiveness of cortical inhibitory circuits. In my talk I will review the evidence showing that aging is related to changes in GABAergic mechanisms and the challenges associated with linking such changes to psychophysical performance.

Friday Evening Posters

Attention: Reward

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Orchid Ballroom

16.401 Visual feedback-related probability learning and its contributions to decision from experience

Tze-Yun Wang[1](ivya99@gmail.com), Shih-Wei Wu[1]; [1]Institute of Neuroscience, National Yang-Ming University

There is accumulating evidence that humans distort information about probability when making visual, motor, and economic decisions under risk. When probability was stated explicitly (decision from description), subjects typically overweight small probabilities but underweight moderate to large probabilities. In contrast, when information about probability distributions over monetary outcomes was acquired through experience (decision from experience), people tended to exhibit the opposite distortion pattern. However, it is not clear to what extent such contrast was due to experience-dependent knowledge of probability per se because probabilities were never learned independently of monetary outcomes in those tasks. In this study we intended to resolve this issue. There were 2 sessions in the experiment. In Session 1, subjects repeatedly sampled from 4 decks of cards each having a unique probability distribution over two possible events that did not carry monetary consequences. After obtaining the sampled result, on each trial, subjects were asked to provide probability estimates. In Session 2, we associated events with monetary rewards in all cards. On each trial, the subjects were presented with 2 decks of cards and asked to choose the one s/he preferred. To prevent any further learning about probability, no feedback on winning was provided during the course of the session. The subjects were instructed that two of the chosen options would be selected at random after the session was completed and executed to determine his/her payoffs. Four subjects participated in the experiment. Subjects showed accurate estimates of probabilities after Session 1. To our surprise, all subjects exhibited a pattern of probability distortion consistent with previous results in decision from description, but not decision from experience. This suggests that when probabilistic knowledge acquired through experience was independent of monetary outcomes, subsequent distortion pattern follows that typically found in decision from description.

Acknowledgement: NSC 99-2410-H-010-013-MY2

16.402 Temporally dynamic changes in the emotion-induced spread of target suppression

Lingling Wang[1](dangdang@psych.udel.edu), Steven Most[1]; [1]University of Delaware

Emotional stimuli often impair perception of subsequent targets, an effect termed emotion-induced blindness. Recent research has revealed that emotion-induced blindness is specific to the location of the emotional stimulus, suggestive of spatiotemporal competition between targets and emotional distractors, where spontaneous prioritization of emotional stimuli leads to suppression of competing perceptual representations linked to an overlapping point in time and space (Most & Wang, 2011). In the present study, we investigated whether the spatially localized nature of the effect is immediate or reflects a spatially dynamic window of suppression that unfolds over time. Two streams of upright scene pictures were presented simultaneously at a rate of 100 msec/item. Participants searched for a target that could appear in either of the two streams. One image (lag-1) or two images (lag-2) prior to the target, an emotional or neutral distractor picture appeared, either in the same stream as the target or in the opposite stream. At lag-1, emotional distractors impaired target perception across both streams to the same extent, whereas at lag-2 emotional distractors produced impairments primarily in the same stream as targets. These results suggest that emotional distractors exhibit spatially localized impairments for subsequent targets, but that this spatial localization emerges over time: the target perception deficits induced by emotional distractors appear initially to reflect target suppression across the visual field but quickly narrow to the location of the emotional distractor.

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16.403 When the valued meet the salient: value-driven attentional capture cannot bypass bottom-up physical salience in visual search

Lihui Wang[1,2](lihui.wang28@gmail.com), Hongbo Yu[2], Qi Chen[1], Xiaolin Zhou[2]; [1]Center for Studies of Psychological Application, South China Normal University, [2]Center for Brain and Cognitive Sciences and Department of Psychology, Peking University

In addition to stimulus- and goal-directed attention, a recent study showed that a task-irrelevant feature can capture attention when it is associated with positive reward (Anderson et al, 2011). In two experiments we investigated 1) whether punishment-related feature can also capture attention, and 2) whether the value-driven capture is conditional. Both experiments comprised of a learning phase and a test phase. In Experiment 1, participants were asked to search for one out of six colored circles and to discriminate the orientation (vertical vs. horizontal) of a line segment in the target circle in the learning phase. The target circle was always in one of the two specific colors, one associated with monetary gain and the other with loss. A similar setting was employed in the following test phase except that the line segment was now embedded in a unique shape. In the test phase response times were longer when trials had distractors with either the gain- or loss-associated color than when trials had no such distractors. This effect was significantly smaller in the control group, who did not receive monetary reinforcement during learning. Given that color singleton is physically more salient than shape singleton in capturing attention (Theeuwes, 1991; Wei & Zhou, 2006), we investigated whether the above value-driven effect is conditional upon the bottom-up salience of color. The same design was used in Experiment 2 except that a specific shape, rather than color, was associated with monetary gain/loss during learning and appeared as a critical distractor in the search of a target letter embedded in a color singleton in the test phase. No additional value-drive capture effect was observed. The contrast between the two experiments suggests that value-driven attentional capture takes place only when the value is associated with features of strong bottom-up physical salience.

16.404 Unconscious control of voluntary task choice through goal priming

Hong Im Shin[1](shin7038@naver.com), Min Shik Kim[1]; [1]Dept. of Psychology, Yonsei University

Introduction: The voluntary task switching paradigm is a helpful method to explore task choice behaviors. Using a voluntary task switching paradigm, we examined whether the unconscious pursuit of goals has an impact on switch costs and task choice behavior. Method: At the beginning of the experimental session, participants were randomly assigned to an achievement goal or a fun goal priming condition. The priming manipulation was carried out through a picture-search task. After that, number tasks were presented, and the participants had to choose voluntarily just one of the two numbers, which were always simultaneously presented in Korean (easy task) and in German (difficult task), to judge the magnitude (relative to 5). Result: The results showed that switch costs in error rates were higher in the fun goal priming than in the achievement goal priming. More importantly, the easy task was more often preferred in the achievement goal priming condition than in the fun goal priming condition, while this task choice bias increased among people with chronically high-achievement motivation. Conclusion: Implications of the outcomes for task switch costs and task choice behavior should be discussed regarding to unconscious goal pursuit and chronic motivation.

16.405 Active attentional suppression of reward-predicting information: Electrophysiological evidence

Risa Sawaki[1](rsawaki@ucdavis.edu), Jane Raymond[2], Steven Luck[1]; [1]University of California, Davis, [2]Bangor University, Wales

In many situations, cues are available that predict reward value of an action without predicting which specific action will result in reward. It may be tempting to focus attention toward these cues, but this could actually distract attention away from the information needed to achieve the reward, causing a performance error (e.g. missing a target because attention was

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focused on the cue). In such situations, cognitive control may require rapid attentional suppression of reward-predicting stimuli in order to maximize performance in an ongoing task. The present study investigated this issue by using a reward-cuing task and ERP measures. First, a cue array appeared, indicating whether a low or high reward would be available on that trial. After a blank interval, a circle target and a square distractor were presented (search array). Subjects were instructed to report whether the circle target had a notch on its top or bottom. A correct response to the search array yielded an immediate low or high monetary reward, as indicated by the preceding cue. Therefore, the reward cue predicted the reward value of the correct response, but it did not predict the location of the target or the correct response. Reaction time to the search array was shorter when the high-reward cue preceded it, indicating that the cue was processed. However, ERP recordings showed that the high-reward cue was actively suppressed (as indexed by the Pd component) and perceptual competition between target and distractor in the search array was weakened on the high-reward trials (as indexed by N2pc component). These findings suggest that a high-reward cue produces an attentional priority signal, but this signal is actively suppressed to maximize performance in the ongoing task.

16.406 **Perceived control and visual uncertainty**

Riccardo Pedersini[1](rpedersini@bcs.rochester.edu); [1]Brain & Cognitive Sciences, University of Rochester, Rochester NY

While humans normally take suboptimal monetary decisions in cognitive tasks, there is growing evidence that they are nearly optimal when those decisions are based on perceptual judgments (see for example Maloney et al. 2006). One widely recognized departure from optimality is uncertainty aversion, a preference for gambles with known risks over gambles with unknown risks (Ellsberg 1961). Last year we showed that our subjects were uncertainty averse when choices involved abstract probabilities, but this attitude was eliminated when abstract probabilities were replaced by visual uncertainty, the uncertainty intrinsic to our visual system and visual stimuli (Pedersini 2011). This year we argue that the reason why visual stimuli eliminate and even reverse uncertainty aversion may be the perception of control over the task. In a series of experiments we compare the subjects' choices in a cognitive task, in which they preferred drawing marbles from an urn with known probability of winning than from one with an unknown probability, and in a visual task, in which they clearly preferred a visual search task over its abstract equivalent. In the visual search, subjects had to look for Ts among Ls on a 1/f noisy background and were awarded 10 pts for correct answers. In the abstract search, subjects saw a 10x10 grid of boxes. They could open 10 boxes and finding at least one green chip would make them win 10 pts and the exact probability of finding a green chip was explicitly given. While subjects showed uncertainty aversion in the marble task, they were uncertainty loving in the search task. They also showed the ability to deploy different levels of effort in the visual search, depending on the possible control they had over the task in different experiments.

Acknowledgement: Office of Naval Research (MURI Program)

16.407 **Non-Monetary Attentional Capture**

Andrew Miranda[1](amiranda06@gmail.com), Navaneethan Siva[1], Evan Palmer[1]; [1]Wichita State University

When stimuli are associated with monetary rewards, they can become more salient, increasing visual search efficiency when presented as targets or decreasing efficiency when presented as distractors. In previous studies, participants were told on each trial about the monetary reward they earned but did not actually receive the money until after the experiment was completed. Thus, changes in salience during the experiment were not due to receiving the money, but the rewarding effect of promised money. The aim of this project was to determine if non-monetary rewards are sufficient to produce the same increase in salience as monetary rewards. We incorporated non-monetary rewards into visual search by using a point system and sound effects to encourage good performance. Points were awarded after each trial for fast and accurate responses with bonus points given for streaks of correct trials. Adapting a paradigm from Anderson, Laurent and Yantis (2011), participants took part in both a training phase and a test phase. During the training phase, the colors red and green were associated with a high reward (a point bonus multiplier of x10 on correct trials) or a low reward (x2 on correct trials). During the test phase, color was irrelevant to the task and previously rewarded targets were sometimes presented as distractors. Results show that reaction times during the test phase were significantly longer on trials in which previously rewarded colors (both high and low reward conditions) were present in the distractor set. Thus, previously rewarded colors increased in salience during the training phase, and automatically captured attention in the test phase. These findings support the idea that non-monetary rewards such as points and sound effects can produce salience priming similar to monetary rewards. This provides researchers another option for encouraging good performance in experiments besides the use of monetary incentives.

16.408 **Exploring the Effects of Video Game Experience and Motivation on Visual Processing**

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Although a number of studies find that video gamers far outperform non-gamers on measures of visual and attentional skill, Boot, Blakely, and Simons (2011) have argued that overt participant recruitment in which gamers know they are being selected for their game experience might induce demand characteristic responsible for superior gamer performance. We used two approaches to explore this issue. First, we recruited gamers and non-gamers (N = 51) covertly and had them perform a search task based on the Useful Field of View task. When gamers had no reason to suspect they were in a study of gamers, gamer and non-gamer performance was equivalent. Hours of experience was not correlated with search accuracy ($r = -11$, $p = .46$). Comparing the 10 most experienced action gamers to the 10 individuals with the least game experience revealed no gamer advantage ($F(1,18) = 1.35$, $p = .26$, $\eta p2 = .07$). We hypothesized that overt recruitment might motivate gamers to perform well. In a second study using the same search task we manipulated motivation directly. Participants completed one block of trials and then were either asked to try harder on the second block, or were asked to treat the second block of trials as if it were a task they normally found enjoyable. Compared to a control group that received no additional instructions between blocks, there was a significant performance improvement for the group asked to try harder (block x instruction interaction: $F(1,24) = 6.20$, $p <. 05$, $\eta p2 = .21$). A similar trend was observed for the group asked to perceive the task as similar to a task they enjoyed ($F(1,23) = 3.31$, $p = .08$, $\eta p2 = .13$). Results highlight the potentially important role of motivation and demand characteristics in studies of gamers.

16.409 **Self mediation of perception**

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We present novel evidence showing that new self-relevant visual associations can affect performance in simple shape recognition tasks. Participants associated labels for themselves, other people, or neutral terms with geometric shapes and then immediately judged if subsequent label-shape pairings were matched. Across five experiments there was a reliable self-prioritization benefit on response times and accuracy which remained across different presentation contexts (with self, best friend, and unfamiliar others in Experiment 1; with self, best friend, and neutral terms in Experiment 2; with self, mother, and neutral terms in Experiment 3). The self-prioritization effect on shape matching increased when stimuli were degraded (self shapes showing weaker effects of degradation), consistent with self information modulating perceptual processing; it led to enhanced target selection in hierarchical figures, and it was associated with a distinct pattern of neural activation. Control studies suggested that the results did not reflect the length or concreteness of the words. The results indicate that associating a stimulus to the self modulates its subsequent perceptual processing.

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16.410 **Sharpening Orientation Tuning with Reward**

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Previous studies indicate that attention enhances the gain of neurons tuned for the relevant feature, maximizing perceptual acuity in the specific context. Recent evidence suggests that reward also enhances perceptual representations of valuable stimuli. However, the precise nature of reward-based modulation on neurons tuned for the rewarded feature is not yet clear. Here, we investigated the effect of reward on orientation tuning, and the degree to which it is affected by context (i.e., target-distractor similarity). To this end, a reward-based variant of the Navalpakkam and Itti (2007) paradigm was employed. During the training phase, subjects searched for an either 45° or 135° oriented target grating among dissimilar (45° apart) or similar (10° apart) distractor gratings. One of the targets was more highly rewarded than the other. Reward-based tuning effect was then measured in the randomly intermixed test phase in which subjects located the target embedded among a spectrum of distractor gratings. When the target and distractors in the training phase were dissimilar, target orientation received attentional gain proportional to the amount of reward. When the target and distractors were similar, however, the shape of the tuning function varied with the amount of reward. For low-rewarded target, gain was applied to the exaggerated target orientation, shifting the tuning function slightly away from the actual target orientation (i.e., optimal gain). For high-rewarded target, interestingly, gain was applied to both target and exaggerated target orientations, making the tuning function asymmetric but still sharply tuned to the actual target orientation. This reward-based sharpening made the performance optimal not only in the training phase but also in the test phase. These results suggest that rewarded stimuli are robustly represented by sharpening the response profile of the neurons selective for the relevant feature in the specific context, which in turn, optimizes the performance.

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16.411 **Task-irrelevant Happy Faces Facilitate Visual Search Performance**

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In everyday environment, there are many objects that attract our attention and arouse our emotion. Thus, the best way to perform the present task efficiently should be to focus on the task-relevant information and ignore the irrelevant one as much as possible. But is this really so? Previous studies showed that subjective positive emotions broaden the scope of attention and promote attention reorientation (e.g. Fredrickson & Branigan, 2005). However, whether objects that arouse our positive emotion affects attentional processing remains unknown. In the current study, we investigated how task-irrelevant emotional information (i.e. faces with emotional expression) affects the performance of visual search, which requires visual attention to search for the target amongst distractors. Participants were presented four different faces with the same emotional expression (happy, angry, or neutral) 150, 400, 800, 1200, and 2000 milliseconds prior to the visual search. In the control condition, four different mosaics or the uniform gray images were presented instead of faces. Following that, faces were disappeared and a search display was presented. The search display consisted of 19 'L's with various orientations and one 'T' which oriented left or right. The task was to report the orientation of 'T' as quickly and accurately as possible. Importantly, participants were explicitly instructed to ignore the faces because they were irrelevant to target locations. Reaction times for the search task significantly decreased when happy faces were presented 400 milliseconds prior to the search display rather than the control condition. However, reaction times did not decrease when faces were replaced with inverted faces or attractive food pictures. These results indicate that the visual search performance was enhanced when the task-irrelevant happy faces were presented prior to the search display. This enhancement disappeared after brief period, suggesting that appearance of task-irrelevant happy faces would modulate our attentional processing temporarily.

16.412 **Positive affect broadens perceptual tuning curves.**

Stefan Uddenberg[1](stefan.d.uddenberg@dartmouth.edu), Won Mok Shim[1]; [1]Psychological and Brain Sciences, Dartmouth College

Previous research has shown that positive mood broadens the scope of visual attention, from facilitating more holistic processing of figures to expanding the spatial extent of one's attentional spotlight (Rowe, Hirsh, & Anderson, 2006). However, it remains unclear whether the broadening effect of positive affect can be generalized to feature space. The present study investigated the hypothesis that positive affect also serves to broaden the scope of feature-based attention, reducing selectivity along a given feature dimension. While undergoing a musical mood induction procedure for each of three affective conditions (positive, neutral or negative) subjects made rapid responses to the presence of a target direction (leftward or rightward) evinced by a peripheral, circular aperture of grey dots. These dots moved coherently in brief pulses, with a different random direction for each pulse (± 80° centered on target direction, with 10° steps) (Busse, Katzner, Tillmann, & Treue, 2008). We extracted perceptual direction tuning curves by reverse-correlating subjects' responses with the motion sequence and compared the width of the tuning curves across three mood induction conditions. The results show that positive affect yields broader direction tuning curves (as shown by greater FWHM) than did negative affect, but not neutral affect. This finding suggests that positive states result in a diffusion of attention across feature space.

16.413 **Fear-Conditioned Arousing Stimuli Enhance Spatial Contrast Sensitivity: Application of the Quick Contrast-Sensitivity-Function Method**

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Recent evidence indicates that emotion enhances contrast thresholds (Phelp, Ling & Carrasco, 2006), and perceptual sensitivity for low-spatial-frequency stimuli (Bocanegra & Zeelenberg, 2009). However, these studies report just the responses to various frequencies at a given contrast or vice versa rather than the contrast sensitivity function (CSF) – the appropriate measure to investigate the interaction between the spatial frequency and contrast. We therefore measured the CSF to provide a more complete description of the early vision as a function of emotional arousal. To acquire the observer's CSF, we adopted the quick-CSF method (qCSF; Lesmes, Lu, Baek & Albright, 2010), a Bayesian adaptive inference with a trial-to-trial information gain strategy. We used a fear-conditioned stimulus (CS) to manipulate observer's arousal level. During the conditioning phase, high or low pitch tones were designated as the CS+, and electrical shock served as the US; a 700-ms CS+ tone was followed by a 200-ms US. After conditioning, observers performed a 2-alternative forced-choice orientation discrimination task in which they judged on each trial whether or not a Gabor patch was tilted counterclockwise or clockwise. Each trial began with a CS tone for 700 ms, followed by a 1000-ms blank, and then a 50-ms Gabor grating (spatial frequencies were from 0.25 to 36 cpd; contrasts were from 0.1 to 100%). To measure the conditioning effect, we measured the skin-conductance response (SCR) across the study. In the arousing condition, participants had a broader spatial frequency range within which they could detect the tilt, reflecting greater CSF bandwidth than in the non-arousing condition ($p < .001$). In addition, the peak CSF sensitivity was shifted to lower spatial frequencies in the arousing condition compared with the non-arousing condition ($p < .005$). Thus, emotional arousal increased overall CSF sensitivity, particularly at lower spatial frequencies.

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Attention: Inattention and attention blindness

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Orchid Ballroom

16.416 **Long Blinks and Optimal Attentional Set** in the Detection of Dynamic Events in Complex Scenes

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We examined the detection of events within scenes composed of many events. Previous results indicate that attentional set is critical: the detection of target events is more accurate when observers focus on a single event type than multiple event types. The present experiments indicate that detecting one event has a negative impact on detecting subsequent events, and that the decrements (blinks) last over 2 sec. After the blink, an optimal attentional set is re-established in favorable conditions. Method. Observers monitored 60 sec streams composed of 144 asynchronous, 4 sec events. Blocks of trials were either single event (1 event type) or multi-event (4 event types). Event types were visually distinctive from each other and had their own critical dimension (color, shape, location, or motion). Multi-task blocks were grouped by event type or distributed (event types intermixed). Detection accuracy for targets was the main measure (false alarm rates <1%). Results. As previously, single-event performance (81% hit rate) exceeded grouped multi-event (64%) which exceeded distributed multi-event (48%). Of most interest were functions relating hit rate to amount of time after an initial target. In single-event and grouped multi-event conditions, there was a 20% drop for targets occurring 0 - 1 sec after an initial target -- a blink. Performance then recovered in a linear manner, reaching asymptote at 3 sec. The asymptote indexes recovery of an optimal attentional set. Complex responses caused less recovery (lower asymptote) -- a less effective

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set. Complex responses combined with distributed multitasking to eliminate reinstatement of set. These data support a detailed interpretation of attentional set in the present situation, in terms of the use and switching of search templates for dynamic event types. And the data indicate that some conditions prevent setting of set.

16.417 **Using magic to reconcile inattentional blindness and attentional misdirection**

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Recently, Memmert (2010) argued for an empirical dissociation between inattentional blindness (IB) and attentional misdirection (AM) paradigms, citing four important differences between protocols within each field of study. Following the lead of Kuhn and Tatler (2005), we have developed a magic trick for use in eye-tracking experimentation that has properties which make it ideal for reconciling the differences highlighted in Memmert's critique, while maintaining the ecological validity that many experiments in IB lack. In particular, it has the malleability to extend and re-evaluate the findings of Mack and Rock (1998) under real-world viewing conditions. In the magic trick, a coin placed beneath a napkin disappears, reappearing under a different napkin. Depending upon the condition, in some instances participants were also required to identify a briefly presented visual stimulus. Appropriately deployed attention during the trial would allow a participant to detect the "secret" event that underlies the illusion, as the event happens in full view and is visible for an average of 550 msec. The magic trick has been used to successfully replicate results across the IB and AM literatures, including the common finding that IB cannot be predicted by eye movements during the period in which the IB stimulus is visible. Rather, IB can only be predicted by fixation patterns and durations following the critical period. We will show how the magic trick can be manipulated to address each of Memmert's points, as well as to test some of the commonly-held psychological intuitions of magicians.

16.418 **Electrophysiological evidence for early perceptual disruption by emotional distractors**

Briana L. Kennedy[1](bkennedy@psych.udel.edu), Jennifer Rawding[2], Steven B. Most[1], James E. Hoffman[1]; [1]University of Delaware, [2]University of Notre Dame

Emotion-induced blindness (EIB) refers to disrupted awareness for items presented soon after an emotionally arousing stimulus. In the present study, we investigated the neural signature of EIB using event-related potentials (ERPs). If EIB is similar to the "attentional blink", we would expect that the emotional distractor would elicit a P300 component reflecting a trade-off in working memory resources with the task-relevant target. Recent behavioral evidence, however, suggests that EIB stems from early perceptual competition between emotional distractors and targets. Participants in the current experiment searched for a single rotated picture that appeared two or eight images (lag-2 and lag-8 respectively) after one of three types of irrelevant distractor picture: emotionally negative, neutral, or "baseline" scene. Pictures appeared in a rapidly presented stream (one image replacing the next every 100 msec). Results showed that at lag-2, target detection was lowest following negative distractors, better following neutral distractors, and best following baseline distractors, with no difference between distractor types at lag-8. Importantly, no P300 was observed for any of the distractor types and the P300 for targets did not mimic the behavioral results. Instead, an early posterior negativity (EPN) was observed approximately 220 msec following both distractors and targets, and the amplitude of this component showed a trade-off that was consistent with the behavioral data. A large EPN was elicited by the task-relevant target picture when it was preceded by a baseline distractor picture, which produced a small EPN. However, an emotional distractor produced a large EPN and resulted in a small EPN for the subsequent target. Neutral distractors were in between these two extremes. These results provide converging neural evidence that EIB reflects competition during early perceptual stages, which differs from the late-stage disruption proposed for the attentional blink.

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16.419 **Dual change detection task reveals the time course of resource demand in VWM process**

Hae-In Kang[1](hennnn@naver.com), Joo-Seok Hyun[1]; [1]Department of Psychology, Chung-Ang University, Seoul, Korea

Change blindness occurs when there are not enough attentional resources to detect a change on an unattended object. A series of experiments were conducted using a dual-task design to examine the time course of change detection process and consequent attentional demands for VWM. Subjects remembered colors of four squares. After a memory delay, another four colored squares were displayed as a test array. Subjects reported if there was any color change in the test array compared to the memory array. While performing the central VWM task, subjects also monitored a sudden abrupt color change among a number of squares displayed at periphery. As the squares at periphery were being displayed without any offset, the abrupt color change was supposed to be perceptually salient. We varied the onset of peripheral change i) at 200ms after the memory array of the central task showed up ii) at the same time as the offset of the memory array, iii) at 500ms after memory array onset, iv) at the same time as the onset of the test array, v) at 48ms after the test array showed up. When subjects only performed the peripheral change detection task alone, the change detection accuracy was above 90%. However, the peripheral change detection became relatively inaccurate when performed together with the central task. The pattern of impairment was only evident if the peripheral change occurred around the onset of memory items for the central task. The performance however was gradually improved through memory delay interval, and was fully recovered around the onset of test items. These results indicate that the early phase of change for consolidating and maintaining memory items into VWM needs more attentional resources than the late phase of change detection in which the memory items are compared against test items.

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16.420 **Examining pupillary response as a psychophysiological predictor of inattentional blindness**

Timothy Wright[1](timwright@psy.fsu.edu), Walter Boot[1]; [1]Department of Psychology, Florida State University

Past research on inattentional blindness has uncovered few reliable individual difference measures that successfully predict failures to detect an unexpected event. Most notably, no correlation exists between primary task performance and inattentional blindness (Simons & Jensen, 2009). This is perplexing as better primary task performance is typically associated with increased effort, which in turn is associated with fewer spare attentional resources to process the unexpected event. Our experiment utilized a psychophysiological measure of effort (pupillary response) to determine whether effort devoted to the primary task is related to inattentional blindness, and whether accuracy is a valid measure of effort in a task such as multiple object tracking. A paradigm similar to Simons and Jensen (2009) was used. Observers' eye movements were recorded as they tracked white T's among white and black distractor letters. Tracking load was manipulated to assess pupillary response as a function of effort devoted to the task. Namely, each block alternated between four targets and one target, with the final block containing the critical trial in which the unexpected event (i.e. a black cross) occurred. The pupillary response of those who noticed the unexpected event was compared to those who did not notice. Results showed that tracking load significantly influenced pupillary response (9% increase in pupil size under high load), $t(100) = 18.95$, $p<.001$. However, the pupillary response of those who noticed the unexpected event did not significantly differ from those who did not, $t(99) = 1.55$, $p= .12$. While these tentative results suggest that effort measured by pupillary response is unrelated to inattentional blindness, a follow-up study is being conducted to replicate and further explore these findings.

Acknowledgement: APAGS/Psi Chi

16.421 **A Flick of the Wrist: Abrupt change in direction of motion induces change blindness**

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Through misdirection and sleight of hand, magicians transform the visual world in front of us without our noticing, effectively inducing change blindness (until they draw attention to what changed). Given that magicians have developed methods for directing attention over centuries, their intuitions about the factors that contribute to change blindness might reveal mechanisms previously unobserved by vision scientists. Here I test one observation made by magician Dariel Fitzkee in Magic by Misdirection: "A sudden change in the direction of a movement, as from a horizontal path of action to a vertical one, in making a pass, is a distraction." Subjects were asked to detect the rotation of a gabor patch in an array of moving gabors. Rotating the patch at the moment of an abrupt change in motion direction did attenuate change detection relative to when the patch rotated during continuous motion. A series of further experiments explored this new phenomenon in order to understand how and why it modulates attention and change detection. Past methods for inducing change blindness involved redirecting attention to preclude localization of a change signal. The current effect may function similarly, perhaps by introducing a motion transient as a result of the direction change or by occupying attention with the recalculation of trajectory.

16.422 The fate of visual object representations under change blindness

Niko Busch[1,2](niko.busch@googlemail.com); [1]Institute of Medical Psychology, Charité University Medicine Berlin, [2]Berlin School of Mind and Brain, Humboldt-University Berlin

How does the visual system keep track of the changes in a dynamic environment? In fact, does it keep track of these changes at all? Observers are usually poor at detecting prominent changes in a scene when the change occurs simultaneously with a brief disruption of the display. This so-called change blindness obviously points to a limit in our ability to represent and process visual scenes. But where exactly is the locus of this limit? One view suggests that the number of objects that can be represented at a time is strongly limited. A different view suggests that as long as the scene is in view, a large number of objects may be represented. However, due to limited stability, these representations may be volatile and easily overwritten by the post-change scene. Both accounts seem to agree that the representation of the changing object is lost under change blindness. In this study, we investigated the fate of object representations when changes go unnoticed. We presented scenes consisting of real world objects, one of which changed on each trial, while recording event-related potentials (ERPs). Participants were first asked to localize where the change had occurred. In an additional recognition task, participants discriminated old objects, either from the pre-change or the post-change scene, from entirely new objects. Participants performed poorly at recognizing pre-change objects compared to post-change objects. This result is consistent with the idea that pre-change object representations are overwritten by the post-change scene. However, ERPs differed between pre-change objects and new objects, indicating that a weak memory trace of the pre-change object had persisted. Importantly, this effect was found even when both localization and recognition failed. This finding suggests that in addition to limited capacity and overwriting, change blindness can also occur when the visual system simply ignores pre-change object representations.

16.423 The difference in perceptual processing between detection and localization of a change

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Visual change detection includes detection proper, localization, and identification (Rensink, 2002), whereas the perceptual processing of these three steps is still unclear. Here, we investigated the differences in perceptual processing between detection and localization of a change by measuring accuracy and reaction time. In the experiment, a fixation cross was presented at the center of a display screen, followed by a test stimulus (presented for 300 ms) after a randomly selected time interval (500, 750, or 1000 ms). Then, cross a blank display was presented for 200 ms, after which a comparison stimulus was presented for 300 ms. The participants were instructed to report whether any of the small bars in the search area had changed by pressing a key. After the detection response, a pointer was presented and participants were required to report whether the change had occurred at the location indicated by the pointer. If information on the occurrence of a change contains information about its location, participants were expected to be able to localize a change whenever they detected it correctly. In the results, participants did not always succeed in localizing a change, even when they had detected it correctly. However, significant differences in reaction times for detection were not observed between when participants succeeded in localizing a change and when they failed to localize it. Thus, it is supposed that the detection of a change was completed before the visual system finished localizing it. To test whether the localization of a change increases reaction times, reaction times for orientation discrimination at the locations of the changes were investigated. Results showed that reaction times were longer when participants succeeded in localization. This may indicate that participants detected in general that the two scenes were different before localizing the change.

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16.424 General and Specific Bottlenecks: Training Differentiates the Attentional Blink from the Psychological Refractory Period

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An important question in Psychological Science concerns the extent to which human information-processing limitations reflect the capacity of general vs. specific cognitive resources. Here we tested whether perceptual (e.g., attentional blink, AB) and decision-making limitations (e.g., psychological refractory period, PRP) occur due to a general, unified bottleneck. To do this we employed a training approach to assess the specificity of practice required to reduce both these impairments. Our logic was that if both limitations respond to the same training regimen then it would suggest they reflect a common limitation. In contrast to previous research that has examined the relationship between the PRP and AB, a key strength of the current approach was that standard AB and PRP paradigms could be employed (in addition to a hybrid AB-PRP task which has previously been used to test this question). Participants completed a PRP task, an AB task and a hybrid AB-PRP task (speeded Task 1 and delayed Task 2) before being allocated to a relevant training group (T1 practice for all paradigms), an irrelevant training group (comparable sensorimotor training) or a control (no training) group. Training groups undertook ~4000 single-task trials across two weeks. At re-test, only the relevant training group showed reductions in PRP and hybrid AB-PRP magnitudes. However, both the relevant and irrelevant training groups showed a significant reduction in AB magnitude relative to controls. This indicates that while task-specific sensorimotor training is required to reduce the magnitudes of the PRP and hybrid AB-PRP, general sensorimotor training attentuates the AB. The findings suggest that while there is overlap in the bottlenecks underlying perceptual and decision-making limitations, the AB also represents a distinct bottleneck in information processing. These findings have implications for understanding the cognitive architecture underlying human information processing and the extent to which training transfers across tasks.

Face perception: Development and aging

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Orchid Ballroom

16.427 Experience Affects Age Biases In Face Processing In Children And Adults

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The study tested recognition of younger- and older-adult faces in two groups of adults (Exp.1; N=35) and 3-year-old children (Exp.2; N=30) differing for the amount of experience with older adults. Participants were tested within a delayed two-alternative forced-choice matching-to-sample task with upright and inverted faces. The magnitude of the inversion effect for each face age was used as a broad marker of configural processing. Results of Exp.1 showed that face age affected adults' recognition accuracy differently in the two groups (Face age x Orientation x Experience;$p<05$). Adults with limited experience with older people exhibited better discrimination of younger compared to older faces in the upright orientation and an inversion effect selective for younger-adult faces (Face age x Orientation;$p<.001$). This processing advantage for younger-adult faces was absent in adults with an average working experience of 10 years in retirement homes, who showed comparable discrimination of younger and older-adult faces and an inversion cost of comparable magnitude for both face ages (Orientation;$p<001$). Exp.2 as well showed that the processing advantage for younger-adult faces was modulated by experience. Unlike adults, however, children showed a generalized inversion effect for both younger and older-adult faces, irrespective of the amount of experience accumulated with older people (Face age x Experience;$p<. 05$). Moreover, in children with limited experience with older people the magnitude of the inversion effect for older faces was marginally correlated with the average number of hours per year of contact with older people ($r=.51$, $p=.054$), suggesting that limited exposure to older people in these children was sufficient to tune configural-processing strategies to older-adult faces. Overall, the study provides further evidence for

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the existence of a perceptual processing advantage for younger-adult faces over faces from other-age groups across the lifespan, and extends previous evidence for a perceptual learning account of such advantage.

16.428 **The Joint Development of Hemispheric Lateralization for Words and Faces**

Eva Dundas[1](edundas@andrew.cmu.edu), David Plaut[1], Marlene Behrmann[1]; [1]Department of Psychology, Carnegie Mellon University

Consistent with longstanding findings from behavioral studies, recent neuroimaging investigations have identified a region of the inferior temporal cortex that shows greater face-selectivity in the right than left hemisphere and, conversely, a region that shows greater word-selectivity in the left than right hemisphere in adults. What has not been determined is how this pattern of mature hemispheric specialization emerges over the course of development. The current study examines the lateralized hemispheric superiority for faces and words in children, young adolescents and adults in a discrimination task in which stimuli are presented briefly in either hemifield. Whereas adults showed the expected left and right visual field superiority for face and word discrimination, respectively, adolescents demonstrated only the right field superiority for words and no field superiority for faces. Although the children's overall accuracy was lower than that of the older groups, like the adolescents, they exhibited a right visual field superiority for words but no field superiority for faces. Moreover, the emergence of face lateralization was correlated with reading competence, measured on an independent standardized test, after regressing out age and absolute face discrimination accuracy. Taken together, these findings suggest that the hemispheric organization of face and word recognition do not develop independently, and that word lateralization, which emerges earlier, may drive later face lateralization. A theoretical account in which competition for visual representations unfolds over the course of development is proposed to account for the findings.

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16.429 **The Effect of Starting School on Preschoolers' Ability to Recognize Child and Adult Faces**

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Although rudimentary skills emerge during infancy (e.g., Morton & Johnson, 1991; Pascalis & de Schonen, 1995; Pascalis, de Haan, Nelson, & de Schonen, 1998), the recognition of facial identity improves into adolescence (Mondloch, Le Grand, & Maurer, 2002). Here we examined the influence of entering school on face recognition. We hypothesize that the increase in exposure to the faces of unfamiliar children that is associated with entering school may lead to improved face recognition for children's faces. To test this hypothesis, we measured the face recognition abilities of preschoolers who began attending school for the first time in September 2010 (school group; n=18) and of an age-matched control group (n=18) not yet in school. Both groups completed a 2AFC task with adult and child faces, presented both in an upright and inverted orientation, at Time 1 (within the first month of entering school for the school group) and at Time 2 (5 months later). A repeated measures ANCOVA revealed a significant main effect of the covariate, age at Time 1, ($p<.0001$), reflecting better overall performance by older participants than younger participants. In addition, there was a significant interaction between time, age of face and group ($p=.047$) that resulted from a significant improvement between Time 1 and Time 2 for child faces in the school group ($p<.0001$), but not the control group ($p=.118$) and no significant improvement for adult faces in either group ($ps<.4$). The results suggest that sudden exposure to a large number of child faces during childhood improves recognition of novel exemplars of this face category. This exposure may shape a child's face-space (see Valentine, 1991) by producing a more stable and accurate norm, as well as refining its dimensions so that they code better for the physical differences that covary reliably with identity.

Acknowledgement: This research was supported by the Canadian Natural Sciences and Engineering Research Council (grant# 9797).

16.430 **Luminance and Chromatic Negation equally affect Human and Monkey Face Recognition in Adulthood and Early Childhood**

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Adult face processing is limited by observers' experience – discrimination ability and face-specific behavioral effects are reduced in out-group faces. Nonetheless, other-species faces phylogenetically close to our own (e.g. chimpanzees) are processed by face-specific "holistic" mechanisms (Taubert, 2009). Presently, we asked whether or not the well-known effect of contrast-negation on face recognition (Galper, 1970) was exclusive to human faces or generalized to monkey faces. Negation disrupts face pigmentation substantially (Russell, 2007), allowing us to examine species-specific use of surface cues as a function of extended visual development. We tested adults (N=24) and children between the ages of 3.5-5 years (N=21) on a 4AFC discrimination task. Trials consisted of four same-species faces: Three identical distractors and a non-matching target. Participants identified the target as quickly as possible using a touchscreen. Adults completed this task using four types of stimuli: (1) The original faces, (2) Luminance-negated faces: Reversed contrast but original chroma, (3) Chroma-negated faces: Reversed chroma, but original contrast, (4) Fully-negated faces: Both contrast and chroma negated. Children completed this task using only the original faces and the fully-negated stimuli. Adults were highly accurate in all conditions. Further, adults' response latencies revealed a main effect of stimulus category (Monkey RTs <Human RTs) and an interaction between luminance and chroma negation, such that the original faces were discriminated more quickly than all others independent of species. Children were also equally accurate across all conditions and displayed the same main effect of species on response time. However, children showed no evidence of a negation effect for either species. Our data thus suggest that human and monkey faces suffer equally from luminance and chroma negation in adult observers, but that children have yet to develop a robust negation effect in early childhood.

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16.431 **Domain-specific development of face memory between age five and adulthood**

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How is the remarkable human ability to discriminate and recognize faces constructed over development? Although early work argued that face recognition develops very slowly, research over the last decade has shown that key signatures of face processing, e.g. the face inversion effect, are present by four years of age (or even earlier). Thus, face recognition seems to be qualitatively adultlike by age four. Here we ask whether face recognition continues to develop quantitatively after age four, whether any such development is specific to faces or instead the result of the development of domain-general mechanisms (e.g. attention), and whether any such development occurs for perception, memory or both. We tested children age 5 to 10 years and adults on memory and perception of faces versus three control stimuli (cars, bodies, scenes). Children's performance in memory increased with age only for faces, but not for other stimulus categories. In the perceptual discrimination task children's performance increased with age to a similar degree for faces and the other visual categories. Thus, we see quantitative, domain-specific development in face memory but not face perception. Our findings implicate domain-specific mechanisms in the development of face memory, but not face perception.

Acknowledgement: The Ellison Medical Foundation, The Simons Foundation

16.432 **Contact affects the own-age bias and neural correlates of face memory in elderly participants**

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Previous studies revealed consistently enhanced recognition memory for same- as compared to other-age faces (own-age bias, OAB) in young adults, but inconsistent results in elderly participants. To resolve these discrepancies, we examined recognition memory and event-related potentials (ERPs)

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for young and old faces in young participants and two elderly groups, which either reported high or low degrees of daily contact with elderly relative to younger persons. As expected, young adults showed more accurate memory for young versus old faces. While no OAB was found in old/low contact participants, old/high contact participants were more accurate with old versus young faces. ERPs in young adults revealed a parietal old/new effect from 500-800 ms (hits > correct rejections) for young but not old faces. While no old/new effect was seen in the old/low contact group, the old/high contact participants exhibited a prominent reversed old/new effect (hits <correct rejections) for old faces. These results suggest that contact may account for earlier discrepant results with regard to the OAB in elderly participants. A behavioral OAB in elderly participants may depend on high degrees of contact towards old people. Moreover, the pattern of ERP old/new effects suggests that contact may affect recollection-based face memory.

Acknowledgement: German Research Foundation

16.433 **Aging Faces and Aging Perceivers: Are There Developmental Changes in Face Space Later in Life?**

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Adults' expertise in face processing has been attributed to norm-based coding, a representation that develops during childhood and may be optimized for own-age faces (Macchi Cassia et al., 2009). Here, we examined how young and older adult faces are represented in face space and the extent to which aftereffects transfer across age and sex categories. In Experiment 1, 16 young (18-26 years) and 16 older adults (62-82 years) were adapted to compressed female older adult faces. Before and after adaptation, they indicated which member of ±10% same-identity face pairs looked more normal; participants judged male and female young and older adult faces. Older adults demonstrated smaller aftereffects than young adults, $p < .05$, but the magnitude of aftereffects did not differ across age and sex categories for either age group (i.e., were not largest for female older adult faces), $p > .10$. In Experiment 2, we examined whether sensitivity to differences in ±10% face pairs varies as a function of participant age and/or face age. Young and older adults (n = 16 per group) were shown ±10%, ±20%, and ±30% same-identity face pairs and indicated which face in each pair appeared more expanded. Accuracy was > 75% in all conditions and did not differ with face age. Young adults were more accurate than older adults, but only for ±10% pairs, $p < .01$. Participants also rated the normality of young and older adult faces that ranged from +60% expanded to -60% compressed in 10% increments. Overall, older adults were less sensitive than young adults, $p < .001$, and both groups demonstrated slightly greater sensitivity to distortions in young faces, $p < .05$. Collectively, these results suggest that the dimensions underlying norm-based coding are most refined for young adult faces and that sensitivity to these dimensions declines in older adults.

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16.434 **Orientation tuning for faces in the Fusiform Face Area and Primary Visual Cortex**

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Filtering faces to remove all but horizontal information largely preserves face-specific processing. Conversely, preserving only vertical face information leads to dramatic recognition impairments. We conducted an fMRI study to explore where in the visual system the horizontal tuning of face perception emerges. Subjects were scanned while viewing blocks of faces filtered to preserve a 20°-orientation range centered either on horizontal, vertical, or oblique (45° and 135°) orientations. Orientation-filtered faces were presented upright, inverted or (phase-)scrambled. We localized Fusiform Face Area (FFA) and V1 in each subject based on independent functional data. FFA responded most strongly to upright-horizontal faces. Upright versus scrambled and upright versus inverted differences in activation were strongest for horizontal faces. In V1, the average activation profile did not show preference for any orientation. We trained linear support vector machines to classify the stimulus category (upright, inverted, scrambled) or decode the orientation content (horizontal, vertical, left-oblique, right-oblique) based on FFA and V1 voxel activation patterns. In the FFA, the classification of stimulus category was well above chance. Furthermore, upright-horizontal faces (≈75%) were classified better than upright-vertical faces (≈60%). The classification of inverted and scrambled faces showed no orientation preference. In V1, classifying stimulus category was better with horizontal than vertical information; in contrast to FFA, this advantage was present for all stimulus categories. When decoding orientation content based on V1 spatial activation patterns, accuracy was high (55%) for upright and inverted faces, but dropped for scrambled faces (≈27%). In FFA, orientation decoding was slightly above chance for upright faces; it was at chance level for inverted and scrambled faces. These results indicate that FFA is tuned to horizontal orientation selectively for upright faces. The orientation tuning profile of FFA was not passively inherited from V1 processing as this region showed horizontal tuning for all tested categories of faces.

Face perception: Social cognition

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Orchid Ballroom

16.437 **"Here's looking at you, kid": Attentional capture by the abrupt onset of direct eye gaze**

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People's sensitivity to eye contact is striking. Studies have revealed that direct eye gaze (faces looking at the participant) is a powerful cue which affects subsequent attentional and cognitive processing. For example, target detection is more efficient close to the location of direct gaze relative to other locations in the environment. Although gaze behaviour in real life interactions is dynamic, gaze stimuli in previous studies have been static - faces either looked toward or away from participants throughout trials. The present study investigated whether gaze that is suddenly directed at participants has an additional attention capture advantage in comparison to static direct gaze or to gaze that suddenly moves in other directions. The task was to identify a target letter presented on one of four faces. Distractor letters were presented on the other three faces. In the main experiment, the initial display consisted of two faces with direct gaze and two with averted gaze. Simultaneous to target presentation, one of the faces with averted gaze switched to a direct gaze (sudden onset direct gaze) and one of the direct gaze faces turned into averted gaze (sudden onset averted gaze). Results revealed that detection times for targets presented on the forehead of the face with sudden onset direct gaze were significantly shorter compared to faces with sudden onset averted gaze, static direct gaze, or static averted gaze. Subsequent experiments investigated the salience of sudden onset gaze relative to static direct gaze and other types of dynamic gaze switching. Overall, sudden direct gaze seems to have an attentional capture advantage over static direct gaze and sudden averted gaze with a similar amount of motion. It is argued that this advantage for sudden direct gaze occurs because it is an extremely salient cue for the initiation of social interaction.

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16.438 **Bad boys and mean girls: Judging aggressive potential in child faces**

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Facial width-to-height ratio (WHR) is a sexually dimorphic trait that is correlated with aggressive behavior in men and with adult and child observers' judgments of aggression in male faces (Short et al., 2011). The sexual dimorphism emerges at puberty, coincident with rises in testosterone (Weston et al., 2007). No correlation exists between WHR and aggressive behavior in women, but observers perceive women with higher WHR as aggressive, although the correlation is weaker for female (r=.40) than male (r=.70) faces (Geniole et al., submitted). We examined whether 9-year-old children's WHR is correlated with aggressive behavior and whether observers' estimates of aggression are correlated with children's WHR. Nine-year-olds played a computer game that measures aggression and were photographed (data to date, n=14). They then rated adult male, and male and female child faces on how aggressively each person would play the game. A group

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of adults (n=24) rated the same faces. There was no correlation between aggressive behavior and children's WHR (r=.076, p>.50). Across faces, the correlation between estimates of aggression and WHR were significant for adult faces (rs=.68 and .70 for adults and children observers respectively, ps<.01) but not child faces (rs=.29 and .21, ps>.05). A 2 (participant age) x 2 (face age) ANOVA indicated that individuals' correlations between estimates of aggression and WHR were higher for adult faces (r=.40 and .30 for adults and children observers respectively) than child faces (r=.16 and .12), p<.001, although single sample t-tests showed that all four correlations were significant, ps<.05. The main effect of participant age and the participant age x face age interaction were not significant, ps>.50. Our results show that observers do not overgeneralize trait perception in adult male faces to child faces and suggest that the correlation between WHR and aggressive behavior in men cannot be attributed to self-fulfilling prophecy.

Acknowledgement: SSHRC

16.439 **Eyes with higher contrast look younger**

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The luminance and color contrast between the eyes, mouth, eyebrows, and the skin surrounding those features ('facial contrast') decreases with age, and faces manipulated to have increased contrast appear younger, while faces manipulated to have reduced contrast appear older (Porcheron et al. 2011 VSS). Thus there is evidence that certain kinds of contrast in the face change with age and are related to the perception of a person's age. Here we investigated contrast between the iris and sclera, which we term 'ocular contrast'. In particular, we investigated the relationship between ocular contrast and age, and between ocular contrast and perceived age. Using a set of carefully controlled full face color photographs of 289 women aged from 20 to 69, we measured the contrast between the iris and sclera of both eyes in the CIELab L* (light-dark), a* (red-green), and b* (yellow-blue) axes. There were significant contrast changes with age in all three channels, due primarily to the appearance of the sclera becoming darker, redder, and yellower. In a separate study, subjects estimated the age of 150 of these faces. Ocular contrast in each of the L*, a*, and b* channels was found to predict the difference between actual and perceived age of the face. Faces with higher ocular contrast in the luminance and b* channels were perceived as younger. Faces in which the sclera was less red than the iris were considered younger than those where the sclera was more red than the iris. Together these findings indicate that ocular contrast changes with age and is a cue that observers use to estimate the age of a person from their face.

16.440 **Making Sense of Others: The Neural Correlates of Perceiving Person Interactions**

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How social expectations shape our perception of people surrounding us has long been considered a core issue in vision science. What has not yet attracted widespread empirical attention, is the question of how perceivers make sense of others who are not encountered in isolation. Put differently, whether people shake hands, take a walk, or have a conversation, they are often witnessed in each other's company. At what stage in the person perception process does sensitivity to such interactions (and their inherent narrative) arise? To explore this issue, we used functional magnetic resonance imaging to measure neural activity while participants viewed images of two people presented on a uniform background. The shown agents were either interacting socially (e.g., involved in a marriage proposal or saying goodbye to each other) or not interacting. Non-interactions were created by presenting the exact same agents as in the interaction condition but not facing each other or by randomly pairing agents facing each other. Compared to these two control conditions, meaningful social interactions elicited reduced activity in cortical areas associated with person perception (e.g., the posterior temporal sulcus) and person understanding (e.g., the dorsomedial prefrontal cortex). In line with neural models of predictive coding facilitating information processing, these results support the view that social expectations shape the way our brains make sense of interacting others not only at an inferential level but also at a perceptual processing stage. More generally, these findings begin to elucidate the perception of person interactions in the human brain.

16.441 **Caucasian and Asian observers used the same visual features for race categorisation.**

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Using the Bubbles method (Gosselin & Schyns, 2001), we recently explored the visual information mediating race categorisation in Caucasian observers (Fiset et al., VSS 2008). Unsurprisingly, the results show that different visual features are essential to identifying the different races. More specifically, for African American faces, Caucasian participants used mainly the nose and the mouth in the spatial frequency (SF) bands ranging from 10 to 42 cycles per face width. For Asian faces, they used the eyes in the SF bands ranging from 10 to 84 cycles per face width and the mouth in the SF band ranging from 5 to 10 cycles per face width. For Caucasian faces, they used the eyes in the SF bands ranging from 5 to 21 cycles per face width as well as the mouth and the region between the eyes in the second highest SF band ranging from 21 to 42 cycles per face width. Here, we verify if the visual information subtending race categorisation differs for Asian participants. In order to do this, we asked 38 Asian participants from Southwest University in Chongqing (China) to categorise 700 "bubblized" faces randomly selected from sets of 100 male Caucasian faces, 100 male African American faces, and 100 male Asian faces. Separate multiple linear regressions between information samples and accuracy were performed for each race. The resulting classification images reveal the most important features for the categorisation of Caucasian, African American, and Asian faces by Asian observers. Comparison between observers of both races reveals nearly identical visual extraction strategies for race categorisation. These results will be discussed with respect to the literature showing differences in visual strategies employed by Asian and Caucasian observers (e.g. Blais et al., 2008).

16.442 **Judging faces on trustworthiness and emotions**

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Determining whether a person is trustworthy or not is a task of importance on a daily basis. This type of judgment based on a face helps determine the course of our social interactions and prevents people from encountering dangers. Oosterhof and Todorov (2008) have shown that judging a face on its level of trustworthiness relies on two principal dimensions: dominance and valence. Judgments along these two dimensions rely in turn on certain characteristics of a face such as inner eyebrows, cheekbones, chins and nose sellion (Todorov et al., 2008). Todorov (2008) has argued that trustworthiness judgments are an extension of emotional judgments, and that a face judged as trustworthy would be judged as happier than a face judged as untrustworthy, which in turn would be judged as angrier. However, this theory is mainly based on studies investigating explicit trustworthiness judgments, which could be driven by subjectivity. We sought to investigate this theory by using a reverse correlation technique that would help reveal and compare the implicit representations of four categories of judgments based on a face: anger, fear, happiness and trustworthiness. Our results show that the region of the mouth is of particular importance in the representation of happiness and trustworthiness judgments, whereas the region of the mouth and the region of the eyes are important in the representations of anger and fear. Results are discussed in terms of comparisons between trustworthiness judgments and emotional judgments.

16.443 **Judgments of mean attractiveness from a set of faces**

Kang Yong Eo[1](gazz11@empal.com), Sang Chul Chong[1, 2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Recent studies showed that the visual system can accurately extract mean emotion, gender (Haberman & Whitney, 2007), and identity from groups of faces (de Fockert & Wolfenstein, 2009). Meanwhile, in the studies of facial attractiveness, it is reported that averageness positively affected facial attractiveness ratings (Masashi et al., 2009) and that facial attractiveness can be assessed in a brief time (Olson & Marshuetz, 2005). Based on these findings, we hypothesized that the ability to judge mean face identity

might play a role in the assessments of mean attractiveness of sets of faces. Through a preliminary experiment, we measured individual attractiveness ratings of 240 faces. In Experiment 1, we investigated how the difficulty levels of mean-identity judgments influenced mean-attractiveness judgments. The difficulty level of mean-identity judgments was defined as the average distance between the individual faces and mean face identity of them. When the average distance was far, it was difficult to judge mean face identity. A set of four faces was presented for 2 seconds and participants sequentially performed two tasks on them (mean attractiveness ratings and mean-identity judgments). The order of the two tasks was randomly varied across trials. We found that ratings of mean attractiveness did not significantly differ from the arithmetic mean of individual attractiveness ratings measured in the preliminary experiment, when the mean-identity task was easy. This result suggests that mean attractiveness judgments follows the arithmetic mean of individual ratings when one can easily judge mean face identity. However, mean attractiveness ratings were significantly lower than the arithmetic mean of individual attractiveness ratings, when the mean-identity task was difficult. We replicated these findings with exposure duration of 500 ms, followed by a phase-scrambled mask for 500 ms in Experiment 2. These results suggest that overall attractiveness judgments depend on our ability to extract mean face identity.

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16.444 **Investigating factors influencing the perception of identity from facial motion**

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Previous research has shown that facial motion can convey information about identity in addition to facial form (e.g. Hill & Johnston, 2001). The present study aims at finding whether identity judgments vary depending on the kinds of facial movements and the task performed. To this end, we used a recent facial motion capture and animation system (Curio et al., 2006). We recorded different actors performing classic emotional facial movements (e.g. happy, sad) and non-emotional facial movements occurring in social interactions (e.g. greetings, farewell). Only non-rigid components of these facial movements were used to animate one single avatar head. In a between-subject design, four groups of participants performed identity judgments based on emotional or social facial movements in a same-different (SD) or a delayed matching-to-sample task (XAB). In the SD task, participants watched two distinct facial movements (e.g. happy and sad) and had to choose whether the same or different actors performed these facial movements. In the XAB task, participants saw one target facial movement X (e.g. happy) performed by one actor followed by two facial movements of another kind (e.g. sad) performed by two actors. Participants chose which of the latter facial movements was performed by the same actor as the one performing X. Prior to the experiment, participants were familiarized with the actors by watching them perform facial movements not subsequently tested. Participants were able to judge actor identities correctly in all conditions, except for the SD task performed on the emotional stimuli. Sensitivity to identity as measured by d-prime was higher in the XAB than in the SD task. Furthermore, performance was higher for social than for emotional stimuli. Our findings reveal an effect of task on identity judgments based on facial motion, and suggest that such judgments are easier when facial movements are less stereotypical.

16.445 **Fishing for faces: Looking behaviour inside and outside the lab**

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The deployment of visual attention to faces has been studied extensively in traditional lab-based experiments over the past thirty years. Despite the breadth of knowledge gained from these studies, little is known about how people behave outside the laboratory in this domain. For example, are faces attended to in the same way during complex real-world interactions as in lab-based studies, where faces are normally static, isolated, and devoid of social context? Here, we recorded fixations made by five observers taking part in a real transaction in a social setting (e.g., buying a coffee or snack), as part of a mobile eye-tracking task on the UBC campus (Foulsham, Walker and Kingstone, 2011). We analysed fixations to the five most relevant faces, defined by proximity, distinctiveness from the background (i.e., where crowds were viewed) and task relevance, for each recording. In a second experiment, we compared these to fixations made by 16 new observers watching videos of the transactions in a lab setting. Fixations to relevant face stimuli were more frequent in lab-based viewing conditions (17%), than in the real-world condition (13%). Moreover in lab-based viewing, there was a strong bias (47% of fixations) towards the faces of those most important to the transaction (e.g., baristas or shop assistants) compared to bystanders within the scene (25%, for real world observers). This study is among the first to investigate attention to faces in realistic situations, and the findings are explored with reference to conventions of social interaction and personality traits/interactional dispositions of the lab-based observers.

16.446 **Kids ignoring adults, and adults ignoring kids: An own-age face bias in attentional gaze cueing**

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Comparable to the other-race effect, an other-age effect exists in which adults and children exhibit improved recognition performance with own-age compared to other-age faces. The scope of the other-age effect however has not been explored. To examine whether an own-age bias influences attentional processes, we designed a gaze cueing task using adults' and children's faces that validly, invalidly or neutrally cued subjects to the onset of a target. Stimulus onset asynchronies (SOAs) of 115ms or 345ms after the gaze cue were used to compare the time course of gaze cueing effects. Two groups, children and adults, completed the task with non-predictive gaze stimuli to test the hypothesis that participants would be more effectively cued by own-age faces. At the 115ms SOA, children demonstrated an interaction between face-type and gaze validity. Their difference in RTs between invalid and valid trials for children's faces was three times larger than the same difference for adults' faces. Adult participants exhibited the reverse effect at the 115ms SOA. Their difference in RTs between invalid and valid trials for adult faces was three times larger than the difference for children's faces. At the 345ms SOA, RTs were significantly faster for valid than invalid trials, but the age of the face had no effect in either group. These results demonstrate that own- and other-age faces differentially engage attentional mechanisms with a bias toward faces that are more socially relevant.

Acknowledgement: Kaminsky Family Honors Research Grant

16.447 **How to read your opponent's mind to win a game of rock-paper-scissors**

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"Mind-reading" has become a common topic in popular culture, suggesting that careful observation of a person's facial features may reveal covert thoughts. The scientific evidence behind the human skill to infer relations between such outwardly visible markers and another individual's cognition is remarkably little and even less is known about whether humans can acquire these from experience. Pupil dilation has been related to a number of cognitive processes and is thus a potential outwardly accessible marker for betraying one's thoughts. Here we tested, with an adapted version of the childhood game "rock-paper-scissors", whether players can increase their chance of winning by exploiting their opponent's pupil. Opponents played a series of games against a computer, while we recorded videos of their eyes. The words rock, paper, and scissors were read out by the computer in random order at 4s intervals, and opponents were instructed to spontaneously select one of these words. Next, the movies and corresponding read-out words were presented to a separate group of players who were instructed to observe and play against the recorded opponents. One out of ten naive players managed to detect pupil dilations and relate them to the timing of their opponent's decisions, and thereby significantly increased their probability to win the game. Once instructed about the pupil's usefulness, all players performed above chance and increased performance by ~50% on average. Since in 40% of trials the pupil contained invalid information about the opponent's choice, we tested a fresh set of 10 players against opponents for which invalid trials were removed. Six of these naïve players exploited the pupil and performed above chance, but most remained unaware of their strategy. This is the first demonstration that people implicitly exploit a subconscious visual skill to gain advantage in a competitive game scenario.

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Binocular vision: Neural mechanisms and models

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Orchid Ballroom

16.450 Processing of first and second order binocular disparity by the human visual system

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In order to study how binocular disparity is detected by the visual system, we recorded short-latency disparity vergence responses (DVRs) from three human subjects. Stimuli occupied the whole screen (48deg H x 36deg V) and were either single sinusoidal gratings or plaids. The single gratings (0.25 cpd, 32% contrast) were oriented vertically (or horizontally) and were presented dichoptically to the two eyes with a crossed/uncrossed (or left-hyper/right-hyper) disparity of 1 deg. As expected from previous studies, these stimuli induced strong short-latency (70 ms) horizontal (or vertical) DVRs in all subjects. The plaids were composed of two gratings having the same spatial frequency and contrast (0.25 cpd, 32% contrast): a vertical (or horizontal) grating with a crossed/uncrossed (or left-hyper/right-hyper) disparity of 1 deg, and an oblique (45 deg) grating with zero disparity. The gratings composing the plaid had thus either horizontal or vertical disparity (first order disparity), whereas the two dimensional pattern had an oblique (i.e., both horizontal and vertical) disparity (second order disparity). When tested with these stimuli, all subjects generated a strong short-latency (70 ms) DVR in the direction predicted by the first order disparity. This DVR was followed ~20 ms later by an additional response in the direction predicted by the second order disparity. The same phenomena were replicated with low contrast (5%) gratings. These results demonstrate that the extraction of second order disparity occurs, but it takes considerably more time than the extraction of first order disparity.

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16.451 Decoding fMRI responses to disparity-defined depth configurations

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Human brain imaging evidence suggests that disparity-defined structures—from simple planes to complex 3D shapes—evoke discriminable responses in multiple brain areas. However, the nature of the representations in different areas remains unknown. We measured fMRI responses to center-surround configurations of two depth planes, examining how (1) changes in the relationship between center and surround and (2) changes in the position in depth of the entire stimulus, affect cortical activity. Observers (N=8) viewed random dot stereograms depicting a central target plane (±3, ±9 or ±15 arcmin) surrounded by an annulus (±6 arcmin). We used multivoxel pattern classification analysis (MVPA) to quantify information about depth configurations in visual cortical areas. First, we contrasted MVPA accuracies when target depth was defined relative to (i) fixation or (ii) the surround. We found that early visual areas (V1, V2) are most sensitive to depth differences expressed relative to fixation. In contrast, higher ventral area LO is more sensitive to the center relative to its surround, suggesting responses related to depth configuration. Dorsal (V3A, V3B/KO, V7) and intermediate ventral (V4) areas appeared equally sensitive for depth differences expressed relative to fixation or the surround. Second, we evaluated how near vs. far decoding changed as a function of disparity difference, finding that performance in most areas increased as the difference between near and far stimuli increased, while performance was constant in LO. Finally, we assessed transfer between conditions (training the classifier on one stimulus configuration and testing on another). We find that responses in LO do not support transfer across position in depth. These results highlight the role of higher ventral areas in computing information about depth configurations, but suggest that depth representations in LO are not fully abstracted and are modulated by the position of objects relative to the observer.

16.452 Investigating disparity organisation in the human early visual cortex with high resolution magnetic resonance imaging (7 Tesla)

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INTRODUCTION. Binocular disparity signals are small spatial differences between the left and right eyes and create the perception of three-dimensional depth. Electrophysiology and optical imaging in primates have associated disparity processing with the thick stripes of the secondary visual cortex (V2). However, imaging at this scale in the human depth system has not yet been demonstrated. Using very high resolution functional magnetic resonance imaging at 7 Tesla (0.75mm isotropic voxels), this study investigates the organisation for binocular disparity in the human visual cortical areas. METHODS. Cortical blood oxygen-level dependent (BOLD) responses were acquired from 4 subjects with good binocular vision whilst viewing binocular stimuli using anaglyph glasses. In the 'depth' condition, the stimulus was divided into a grid of 3 x 3 squares. The central square contained a fixation cross, while the disparity of the surrounding squares changed every second to a random disparity between ±0.3°. Subjects viewed the 'depth' condition for 16 seconds, alternating with 16 seconds of uncorrelated or random dots in depth. Each subject performed 8 repeats of the 3 minute scan. Data were acquired on 2 separate days for 2 subjects to test reproducibility. Standard retinotopic mapping data obtained at 3 Tesla were used to define the primary visual cortex (V1) and extrastriate areas (V2, V3 and V3a) for each subject. RESULTS. Discrete clusters of voxels responding to the 'depth' condition were predominantly found in extrastriate cortex, including small regions of V1. Reproducibility was evident both across runs within sessions, and across the repeated sessions. CONCLUSION. High-resolution fMRI suggests a functional organisation for disparity processing in the human early visual areas, indicated by a repeatable clustering of responses broadly consistent across individual subjects. Further investigation will examine whether there is fine grain organisation within these clusters of disparity sensitivity.

16.453 Boundary contour of binocular rivalry stimulus affects activities in ocular dominance columns (V1) of anesthetized macaque monkeys

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Psychophysical studies reveal that perceptual dominance during binocular rivalry (BR) is predisposed to the rivaling image with the strong boundary contour (BC) (Ooi and He, 2006). To reveal whether such a BC-based BR perception can be contributed by activities in cortical area V1, we used intrinsic signal optical imaging to measure the neuronal population response in anesthetized and paralyzed macaque monkeys. The basic BR stimulus comprised a 1.5 deg grating disc (3 cpd) surrounded by an orthogonal grating background (5x5 deg) in one half-image (fixed-BC). The other half-image had a grating disc whose orientation was orthogonal to the fixed-BC grating disc. The saliency of the disc's BC was manipulated by phase-shifting its grating relative to the surrounding grating of the same orientation (variable-BC). Increasing the phase-shift strengthens the BC. We rendered the BR stimulus in orthogonal motion (2 c/sec) and measured cortical activities in 3.5-second windows. We found clear ocular dominance maps corresponding to the eye exposed to the fixed-BC half-image. The strength of the ocular dominance pattern decreases as the BC strength in the fellow half-image (variable-BC) increases. This trend parallels the human psychophysical observations of BC strength influence on BR. We also found the ocular dominance/suppression-like activities are stronger in the cortical areas representing the BC than those representing the interior of the grating disc. Separately, we used pattern classification method to estimate the dynamic dominance scores based on sampling at 4 Hz over 60 seconds. We found a longer mean dominance duration associated with the eye simulated with strong BC. Altogether, the similarity between the macaque V1 neuronal population responses and human psychophysics indicates V1 contributes to BC-based BR. More generally, the data suggest BR is an integral mechanism in binocular surface representation.

16.454 **Cyclovergence is controlled by both interocular correlation and interocular velocity difference mechanisms.**

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Eye alignment is controlled visually on horizontal, vertical, and torsional axes. Torsional alignment depends specifically on vertical disparity of opposite sign in the left and right hemifields. Previous studies used static patterns with changing disparity, which include both interocular correlation (IOC) and interocular velocity difference (IOVD) information. We tested the effectiveness of each for driving cyclovergence. Method: Three human subjects wearing scleral search coils and anaglyph glasses viewed a 76 degree diameter circular field of 1000 random dots. The IOC stimuli contained the same random dot pattern in each eye (100% correlation). Dots were replaced in each frame (60Hz), to remove monocular motion information. The IOVD stimuli contained a different random dot pattern in each eye (0% correlation). Dots were unchanged throughout the trial so that monocular motions were visible. Cyclo disparity for both stimuli was sinusoidally modulated (0.33 Hz, peak velocity 10 deg/sec). IOVD was also tested with 30 and 90 deg/sec stimuli. The response measure was the amplitude of cyclovergence at 0.33 Hz. Results: Both classes of stimuli were effective in driving cyclovergence. Responses to IOC stimuli had gains ranging from 0.1 to 0.2, consistent with previous reports using static patterns. Responses to IOVD stimuli were weaker, with gains of .05 to .15 at 10 deg/sec. Higher velocity stimuli did not increase response amplitude appreciably, so the slowest stimulus tested had the highest gains. Conclusions: Responses to the IOC stimuli establish that cyclovergence can be driven by a correlation based disparity mechanism in the absence of monocular motion information. Responses to the IOVD stimuli establish that cyclovergence can also be driven by opposed monocular motions in the absence of interocular correlation. These results extend findings from psychophysical studies of horizontal disparity, establishing that these two mechanisms also serve reflexive eye alignment control.

16.455 **Predictive Remapping of Binocularly Fused Images under Saccadic Eye Movements**

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How does the brain maintain stable fusion of 3D scenes when the eyes move? Every eye movement causes each retinal position to process a different set of scenic features, and thus the brain needs to binocularly fuse new combinations of features at each position after an eye movement. Despite these breaks in retinotopic fusion due to each movement, previously fused representations of a scene in depth appear stable. This is illustrated by moving the eyes after fusing binocular or monocular ("Magic Eye") stereograms. A neural model proposes how the brain does this by unifying concepts about how multiple cortical areas in the What and Where cortical streams interact to carry out 3D boundary and surface perception, spatial attention, invariant object category learning, predictive eye movements, and learned coordinate transformations. Data from single neuron studies and also from psychophysical studies of covert visual attention shifts prior to eye movements (Cavanagh et al., 2010; Duhamel and Goldberg, 1992; Gottlieb, 1992; Gottlieb and Snyder, 2010; Melcher, 2007; Rolfs et al., 2011) are explained. The model clarifies how perceptual, attentional, and cognitive interactions among multiple brain regions (e.g., LGN, V1, V2, V3A, V4, MT, MST, PPC, LIP, ITp, ITa, SC) may accomplish predictive remapping as part of the process whereby view-invariant object categories are learned. This model builds upon earlier neural models of 3D vision and figure-ground separation (e.g., Grossberg 1994; Grossberg and Yazdanbakhsh, 2005) and of the learning of invariant object categories as the eyes freely scan a scene (Cao, Grossberg, and Markowitz, 2011; Fazl, Grossberg, and Mingolla, 2009). A key process concerns how an object's surface representation generates a form-fitting distribution of spatial attention, or attentional shroud, in parietal cortex that helps to maintain the stability of multiple perceptual and cognitive processes as the eyes freely scan a scene.

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16.456 **Contrast Gain Control in Stereo Depth and Cyclopean Contrast Perception**

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Energy models have been developed for stereo depth perception in which the strength of stereo signal is proportional to the product of signal contrasts in the two eyes (Cormack et al, 1991). Although human subjects can see stereogram when considerable contrast difference exists between left and right eyes (Legge & Gu, 1989), how contrast gain-control functions in stereo depth perception has not been systematically investigated. Recently, we developed a multi-channel contrast gain-control model (MCM) for binocular phase and contrast perception (Huang et al, 2011; Huang et al, 2010) based on a contrast gain-control model of binocular phase combination (Ding & Sperling, 2006). In an attempt to extend the MCM to simultaneously account for stereo depth and cyclopean contrast perception, we systematically manipulated the contrasts of the dynamic random dots presented to the left and right eyes, and measured both the disparity threshold for depth perception and the perceived contrast of the cyclopean images. RDSs with all possible combinations of five contrasts, ranging from 0.08 to 0.4, were used in the experiment. We found that both disparity threshold and perceived contrast depended strongly on the signal contrasts in both eyes, exhibiting characteristic binocular contrast-gain control properties. The results were well accounted for by our extended MCM model, in which each eye exerts gain-control on the other eye's signal in proportion to its own signal contrast energy, and also gain-controls over the other eye's gain-control; stereo strength is proportional to the product of the signal strengths of the two eyes after contrast gain-control, and the perceived contrast is computed by combining contrast energy from the two eyes. The new model provided an excellent account of disparity thresholds and the perceived cyclopean contrasts with a single set of parameters ($r2=0.92$). It also accounted for some interesting results in the literature (Legge & Gu, 1989).

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16.457 **Reciprocal inhibition between binocular energy-model units can account for the reduced response to disparities in anti-correlated stereograms**

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Our 3D stereo depth perception depends on disparities between the two eyes' images, arising from their different views on the world. This process is believed to begin in primary visual cortex, V1, where many neurons are tuned for binocular disparity. Their response is well described by the binocular energy model (Ohzawa et al. 1990, Science 249:1037). Because the energy model effectively implements cross-correlation of the left and right eye images, it makes a specific prediction about what happens when one eye's image is polarity-inverted, i.e. replaced with its photographic negative, so that black pixels become white and vice versa. For these anti-correlated stimuli, the energy model predicts that the disparity tuning should simply invert; i.e. the disparity tuning curve should undergo a phase change of π with no change in amplitude. In fact, although disparity tuning curves of real V1 do usually invert for anti-correlated stimuli, they are also reduced in amplitude (Cumming & Parker 1997, Nature 389:280). Several modifications to the energy model have been put forward to account for this (Read et al. 2002, Vis Neurosci 19:735; Lippert & Wagner 2001, Neuroreport 12:3205; Haefner & Cumming 2008, Neuron 57:147). However, recent evidence suggests that none of these models is sufficient on its own (Tanabe et al. 2011, J Neurosci 31:8295). Rather, the latest evidence points to reciprocal connections between V1 neurons with different disparity tuning. Here, we present our first attempts to build a quantitative model along these lines which can account for the dynamics of the physiology data.

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16.458 **What is binocular fusion?** Multiplicative combination of luminance gradients via the geometric mean

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When images in the two eyes are sufficiently similar, they are 'fused'. Fusion has motor (vergence) and sensory components. When vergence is prevented, sensory 'fusion' of disparate images still occurs, but the nature of this fusion has received curiously little attention. Summation of signals from the two eyes is fairly well understood, and seems the obvious basis for fusion. But summation of disparate edges should cause the fused edge to appear more blurred. We tested this by studying the perceived blur of single edges with vertical disparities that spanned fusion and diplopia. Single, horizontal, Gaussian-blurred edges (blur, B=1.6 to 40 minarc) were presented to each eye at various disparities (0 to 4B), or were added together in the same eye (monoptic control). Perceived blur was measured by blur-matching, using a 2-interval forced-choice method. In monoptic conditions, matched blur increased with disparity in the fusional range (0 to 2B) as expected. But, surprisingly, when the two edges were in different eyes (dichoptic), matched blur remained almost constant, and did not increase with disparity. This shows that fusion preserves the sharpness or blur of each eye's image, and that fusion cannot easily be explained by summation or arithmetic averaging of spatial signals across the eyes. We show that fusion of this kind occurs if (a) each monocular signal is the spatial derivative (gradient profile) of the input edge, and (b) binocular combination is the contrast-weighted geometric mean of these signals. This achieves positional averaging ('allelotropia') without blurring or smearing the edge information.

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16.459 **Noise alters binocular combination**

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When identical sinewave gratings are presented to the two eyes, with noise superimposed in only one eye, the eye with the added noise dominates the binocular combination (Ding and Sperling, 2006, 2007). This surprising result can be accounted for by the Ding-Sperling contrast gain-control model. However, because they only tested limited conditions, the details about how the added noise affects binocular combination remain unclear. In the present study, we examined binocular combination in normal observers using sinewaves with nine interocular contrast ratios (ISCR) and with band-pass noise (1.26 octaves bandwidth) added to both eyes with nine (3x3) different combinations of noise contrast (INCR). The two eyes' sine waves had identical spatial frequency (SSF) (0.68 cpd or 1.36 cpd) with a 90 deg phase shift, but differed in contrast. The added bandpass noise was perfectly correlated in two eyes. The center frequency of the noise (NSF) was 4 or 8 times that of the sinewaves. We tested a total of 9(ISCR)x9(INCR)x2(SSF)x2(NSF) = 324 experimental conditions. The observer's task was to indicate the apparent location (phase) of the dark trough in the perceived cyclopean sine wave relative to a black horizontal reference line. The perceived phase was measured as a function of the interocular contrast ratio, which shifted systematically from the left eye to the right eye as the contrast ratio R/L varied from 0.25 to 4. Importantly, the behavior of this phase curve was affected in two ways by the added noise: (1) The phase curve shifted toward the eye to which the stronger noise was added, and shifted back when the identical noise was also added to the other eye; (2) The slope of the phase curve became more shallow (apparent weaker mutual interocular inhibition) when stronger noise was added. These results are well predicted by the Ding-Sperling contrast gain-control model.

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Color and light: Mechanisms

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Vista Ballroom

16.501 **The coding of hue revealed by discrimination of chromatic textures**

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Purpose: To investigate how hue is coded for purposes of processing texture. Specifically, we test a model proposing that hue-selective units all share tuning functions of the same shape F but centered on different hues so as to achieve uniform coverage around the hue circle. Methods: We used eight equiluminant hues drawn from a circle of maximal achievable radius on our monitor in an equiluminant plane of DKL space. Different textures (hue scrambles) were created by randomly mixing small squares of these 8 hues in varying proportions. On a trial, the participant strove to detect the orientation of a square wave whose texture-defined bars alternated between two different hue scrambles. In a given condition, the difference between the histograms of the two textures to be discriminated on a given trial was always strongly correlated with a particular "seed" histogram difference D. We measured the influence ID(h) exerted by different hues h on the participant's judgments. Results: The model being tested predicts that ID should be the convolution of D with some tuning curve F. This prediction was supported for several different seeds D. For one participant the tuning curve F fell to half-height over an angle of around p/4 around the hue circle; for the other observer, F fell to half-height over an angle near p/2. Conclusions: For purposes of texture processing, hues are coded by the activation produced in an ensemble of units all with tuning curves sharing the same, fairly broad shape but centered on different hues uniformly around the hue circle.

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16.502 **Testing the role of color information in primal sketch generation**

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The visual system is capable of extracting biologically-relevant information from a large amount of input data but, due to limited processing capacity (Lennie, 2003), extensive data reduction must operate at an early stage (Attneave, 1954; Barlow, 1961), by creating a compact summary ("sketch") of relevant information to be handled by further levels of processing (Marr, 1982). Color in natural scenes is a rich source of information, and a fundamental question is whether color is sufficiently important to justify its implicit computational load at this stage. A recent model of early visual processing (Del Viva & Punzi, VSS-2006) proved successful in obtaining sketches that retain the visual features human observers exploit for image discrimination (Del Viva et al. VSS-2010). This model also predicts that the use of color does not provide a significant improvement in the information content of such sketches, over the use of luminance alone (Punzi, Del Viva & Shevell, VSS-2010). Here, to study whether this early stage makes use of color information, we measured the discriminability of briefly presented sketches (20 ms) containing either color or luminance information or both, based on image representations expressed in the MacLeod and Boynton color space. The results showed that performance obtained with equiluminant sketches (only one bit of color information) was much lower (chance level) than that with dark/light grey sketches (only one bit of luminance information). Results showed also that adding an extra bit of color to the luminance bit did not increase performance, which was much lower than that obtained with 2 bits of luminance information. These results suggest that early visual representations may not use color. Instead, color may be more suitable for a separate level of processing, following a rapid, initial luminance-based analysis.

16.503 **Normal chromatic VEPs in a case of cerebral dyschromatopsia**

Hannah Shoenhard[1](h.m.shoen@gmail.com), Chad S. Duncan[2], Chris Jones[2], Michael A. Crognale[2]; [1]Keck Science Department, Scripps College, [2]Psychology Department, University of Nevada-Reno

The chromatic visual evoked potential (crVEP) was used to test the integrity of the chromatic pathways in a patient with bilateral damage to the ventral occipitotemporal cortex. The patient participant was a 46 year old female who experienced a vertebral artery tear that ultimately resulted in cerebral infarct in 2005. Her primary symptoms included achromatopsia, prosopagnosia and topographical agnosia. She also exhibits quadrantanopia with sparing of the macular region. We recently administered a battery of standardized color tests that revealed some improvement in color discrimination. However, significant generalized impairment (dyschromatopsia) remains in agreement with her self-report. Contrast response functions were obtained with the crVEP by way of onset/offset presentations of isoluminant sinusoidal gratings modulated along the LM or S axes of color space. Functions were constructed from amplitudes and latencies of the major CII component and compared with those from an aged-matched population with normal trichromacy. Despite occipitotemporal damage and reduced color discrimination, contrast response functions indicate responses well within the normal range. These results suggest that color processing beyond those stages revealed by the CII component of the spatio-chromatic VEP can be selectively damaged in cases of cerebral dyschromatopsia.

16.504 **Application of fMRI adaptation to characterize the neural representation of color.**

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Color names may be used to divide the continuous spectrum of color percepts into discrete categories. We asked whether there is a transition from a continuous towards a categorical representation of color along the visual pathways from V1 to ventral extra-striate cortex. Ten subjects performed a behavioral color categorization task on 10 stimuli that varied along a green-blue continuum. Separately, these stimuli were presented in an fMRI experiment that employed a continuous carry-over design. The fMRI measurements were obtained while subjects performed an orthogonal attention task. Retinotopic mapping data and a chromatic vs. achromatic localizer scan were also collected. The behavioral data revealed the expected categorization, with a transition from "green" to "blue" labels occurring in the middle of the continuum. The fMRI data were modeled for both the direct effect of a stimulus upon response as well as the adaptive effect of a given transition between stimuli. There was a recovery from adaptation within posterior visual areas that was related to the magnitude of the color stimulus transition. Within V1 and in ventral extra-striate cortex, this recovery from adaptation had a linear relationship to stimulus change. In ongoing analyses we are testing for categorical representation by examining the response to stimulus changes that cross the categorical boundary as compared to those that do not.

16.505 **Peripheral photopic sensitivity to melanopsin and cone photopigments**

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A subset of retinal ganglion cells contains a photopigment, melanopsin, and is intrinsically photosensitive. Melanopsin is routinely described as a "non-visual" pigment, perhaps to highlight its role in functions like pupil dilation and circadian rhythms. However there is no decisive evidence as to whether light can or cannot be seen through the melanopsin pathway in healthy humans. We report measurements and analyses that estimate the influence of melanopsin absorptions on the visibility of lights presented in the healthy human peripheral retina. We ask whether light visibility in photopic conditions is better described as 3-pigment (cones only) or 4-pigment (cones and melanopsin). To analyze whether a fourth photopigment contributes to peripheral photopic visibility, it is necessary to deliver well-controlled light signals using at least four independent primaries. We built a display device capable of accurately delivering six independent primary lights (VSS 2011). Individual variability of inert lens pigments and photopigments optical density makes it difficult to specify a light absorbed by melanopsin but not by cones. Hence, we used a different approach that compares the 3- and 4-pigment predictions. A 3-pigment model predicts that the least visible stimulus (LVS) will cause no change in cone absorptions; with perfect calibration it will be invisible. In a 4-pigment model the LVS is determined by the neural pathway sensitivities and may cause cone absorptions. We collected detection thresholds to many four-primary stimuli. We could not reliably identify an invisible stimulus, but we could estimate a reliable LVS. We estimate that the LVS causes significant numbers of cone absorptions. Furthermore, the optimized 3-pigment model systematically underestimates the sensitivity of test lights designed to produce no cone absorptions. These results suggest a small but measurable peripheral sensitivity to absorptions in four, not three, types of photopigments.

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16.506 **Quantifying the Watercolor Effect with Cortical Responses**

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Introduction: The watercolor effect is a visual phenomenon that occurs when bright colored lines are juxtaposed with darker lines on an achromatic background, forming patterns that suggest figure and ground. The colors of the lines appear to seep into the surrounding regions and cause a change in the percept of the colors of these regions. The present study investigated the cortical activity invoked by this illusion by measuring physiological responses as reflected in the visual evoked potential (VEP). Methods: VEPs were recorded from participants in response to stimuli presented on a CRT. Stimuli comprised patterns of colored lines that induced the watercolor illusion as well as control patterns wherein the identical lines were repositioned such that the illusion was eliminated or greatly reduced. Presentations of the two patterns were randomly intermixed. A psychophysical color matching paradigm was used to quantify the perceptual strength of the illusion independent of the VEP results. In further experiments, spatial, temporal, and chromatic parameters of the stimuli were systematically modified to quantify their respective effects on the strength of the illusion and the resultant VEP. Results: Some but not all of the VEP components reflected changes in the perceived illusion arising from systematic changes in the characteristics of the stimulus. Conclusion: Our findings suggest that changes in the strength of the watercolor illusion and perhaps other color induction illusions can be objectively quantified using components of the VEP.

16.507 **Testing model predictions of induced visual fading**

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Simons et al. (2006) showed that some visual transients can induce massive scene fading, in which a low pass filtered photographs of a natural scene fades to uniform luminance and color. At last year's VSS, Francis & Kim (2010) explained these phenomena with simulations of the FAÇADE model (Grossberg & Mingolla, 1985a,b; Grossberg, 1997). In the model, oriented boundary responses to luminance edges undergo adaptation, and when the adaptation is substantial enough the weakened boundaries are no longer able to trap signals that represent brightness and color in a diffusive surface filling-in process. The effect of the boundary adaptation was frequently heightened by changes in the luminance edges, such as the offset of black disks and a global luminance decrement. Overall, the model's behavior closely matched the findings reported by Simons et al. New simulations of the model explore the time course of the hypothesized adaptation and predict that the degree of fading should be positively related to the on time of the inducing black dots. We tested this prediction with a variation of the Simons et al. (2006) experiment, where observers made a judgment of surface homogeneity within a demarcated region after the offset of the dots. This new methodology avoids some possible hysteresis and criterion biases that might have been part of the Simons et al. study. As predicted by the model, reports of homogeneity increased with the duration of the black dots. The findings confirm the model's prediction and lend validity to its explanation of the earlier data.

16.508 **Chromatic signal detection on a heterochromatic texture with a color distribution away from an adaptation color**

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It is an interesting issue to clarify properties of chromatic mechanisms that operate for colors away from an adaptation color. We employed the Classification Image method to compare the effects of heterochromatic noise on color perception for colors near and away from an adaptation color. The stimulus was two squares with an identical signal chromaticity each of which was superimposed on a chromatic noise textures composed of small square elements. Both signal and noise chromaticities were defined in the isoluminant plane of the DKL color space. The signal color direction was on either the four non-cardinal directions (45, 135, 215, or 315 deg). We had two experimental conditions regarding the noise color distributions: "near" and "away" conditions. For the away condition, the center of the noise color distribution was set at a color on the same color direction as the signal color. For the near condition, the distribution center was set at the adaptation color. The observer requested to answer which signal square seemed to have higher chromatic contrast. Classification Images (CIs) were derived from differences between two averaged noise textures corresponding to 'higher contrast' and 'lower contrast' categories defined by the observers' responses in each color condition. In the results, the color directions of the colors in the signal square region of the CIs did not necessarily correspond to the signal directions, suggesting some effects of properties of chromatic mechanisms on chromatic signal detection. In addition, they had large individual differences only for the away condition, while the perceptual chromatic contrast on a uniform stimulus measured in an additional experiment did not show such large individual differences. These results may suggest the existence of chromatic mechanisms whose individual differences become clear for colors away from an adaptation color only on a heterochromatic texture.

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16.509 Colour constancy of liquid materials under various chromatic illuminations

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Illumination changes cause alterations in reflectance of object surfaces, while perception of surface colour tends to be constant because of colour constancy. Liquid colour, however, appears drastically different under various chromatic lights. In order to investigate why there is much less effect of colour constancy on liquid colour, we investigated the perception of liquid colour under various chromatic lights. The targets were coloured liquids made by watercolours in a transparent glass container with the dimension of 10 (height) x 10 (width) x 4 (depth) in centimetres. Targets were red, orange, yellow, yellow-green, green, blue, violet, or pink in colour. For each condition, one of the eight coloured targets was placed against a white background (Munsell value N9) and was illuminated by one of six chromatic lights (red, yellow, green, blue, purple, and the illuminant A (ill-A)). The observer was asked to evaluate the colourfulness and hue of the target using an elementary colour naming method, and to evaluate the transparency of the target with the method of magnitude estimation. In order to examine how the illumination colour influences the perception of liquid colour, we compared changes in the colourfulness with the excitation purity in CIE xy-coordinates (1931). The excitation purity of the red target was 20% greater when illuminated by the red light compared to when it was illuminated by the ill-A. On the contrary, the colourfulness was reduced by 70% in the same condition. The reduction is twice as much as the colourfulness for a red paper with the same xy-coordinates as the red liquid target under ill-A. This indicates that there was much less colour constancy effect for the liquid colour than for object surfaces. Differences and similarities with the characteristics of colour constancy between object surfaces and liquid materials may elucidate mechanisms behind the colour appearance for liquid materials.

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16.510 Temporal aspects of contour induced negative and positive color afterimages.

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Saturation of negative color afterimage is almost doubled when it is surrounded by a luminance contour (inducer) in the test phase. In addition, a positive rather than a negative afterimage is observed when the inducer is presented to the eye opposite to the adapted eye (Sato et.al., VSS2011). The main objective of this study is to clarify the relationship between the two contour-induced afterimages by comparing temporal aspects. First, we measured simple duration of the two induced-afterimages. After 1sec monocular adaptation to a red or green four-point star, an inducer, a black surrounding contour was presented to the same or opposite eye. Monoptic/no-inducer condition was also included for control. Observers judged the afterimage color and pressed a button until the afterimage disappears. Perceived after image was negative for monoptic and positive for dichoptic contdition as in our previous report. Although the perceived color was stronger with inducer for monoptic presentation, the averaged duration was approximately the same for all three conditions (2.0 sec). Next, we introduced an ISI between adaptor and inducer (0 to 677 ms). It was found that "no-afterimage" response becomes dominant for ISIs longer than 300ms in both monoptic /negative and dichoptic /positive conditions. There was a time-window shorter than the duration of ordinary afterimage. Inducers are effective for both induced-afterimages when it is presented within this time-window, but it masks the afterimage when it was presented beyond the limit. This similarity, together with the similarity in simple duration, suggest that a common cortical mechanism is involved in the two phenomena, since dichoptic afterimage is very likely to be cortical. The width of time-window that is much shorter than the duration of ordinary negative afterimage suggests that the inducer is effective only to certain fast-fading component. It captures some fast cortical component and preserves it.

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16.511 Colour Constancy by Illumination Matching in Real World Scenes

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Computational models predict that colour constancy should improve with increasing numbers of distinct surface reflectances in a scene. The presence of familiar objects may improve constancy by providing reference surfaces for calibration. Colour constancy may also be optimal for daylight illuminations in which it evolved. To probe these potential influences, we have developed a colour constancy measurement that does not require explicit colour matching between objects or achromatic surface adjustment. Here we measure colour constancy by matching illuminations. We used a tuneable illuminator that emits diffuse, nearly uniform light into an enclosed grey box (h35,w65,d55 cm) containing either a colour checker chart or a banana; participants viewed the scene through a viewport. Target illuminants were taken from the daylight locus and an orthogonal locus with the same correlated colour temperature (CCT). Participants (n = 6) were asked to adjust the illumination in 'warmer' or 'cooler' directions by using two keys on mobile, black keypad, placed on the box floor; keypresses changed the chromaticity in steps of 1 ΔE along one of the loci, depending on trial block. Participants initially dark adapted for 5 minutes. Each trial began with 10 seconds exposure to the target illumination. A sound signalled an illumination change (to a random chromaticity on the designated locus) and the start of the (untimed) adjustment phase. Accuracy was measured as end-distance from the target illumination in perceptually uniform space. For adjustments along the orthogonal locus, accuracy was higher in the presence of the colour checker chart than the banana, ($p <.05$). In the presence of the checker, higher accuracy was obtained along the orthogonal than the daylight locus ($p = .05$). Colour constancy corrections thus seem biased towards the daylight locus, and off-daylight-locus illuminations are corrected for more effectively through multiple reflectances than single familiar objects.

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16.512 Effect of material perception on color constancy

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It has been shown that color constancy is improved in real environments compared to simple two-dimensional patterns. This fact suggests that natural environment is important for color constancy. Natural environment consists of a variety of materials and they could contribute to recognizing illumination and obtaining stable appearance of objects. In this study, we examine whether the materials of a test stimulus influence to the degree of color constancy. We built a booth arranged like a normal room illuminated by fluorescent lamps with correlated color temperature 5000K or 2700K. Test stimuli made of papers, plastic, wool were prepared. Four colors (gray, yellow-green, orange, and purple) were tested for each material. Observers evaluated the color appearance of test stimulus using an elementary color naming method. Two viewing conditions were tested: a natural viewing condition and a limited-view condition in which observers only viewed a test stimulus through a black viewing box. The results showed that in the natural viewing condition, differences on the color appearance of test stimuli under two illuminations were small, meaning good constancy. However, they did not show any clear differences between materials. In the limited-view condition, differences in color appearance between two illuminations were generally large, suggesting the low degree of color constancy. Some results, however, showed good color constancy even though the surrounding of test stimuli was dark. We further tested an additional condition using test stimuli with uniform color on a CRT monitor. The results suggested that the high degree of color constancy in the limited-view condition was due not only to an adaption in lower level but also material perception. Our results imply that material perception would not have large influence to color constancy in normal environment, whereas it would contribute to color constancy in a condition lacking information on natural environment.

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16.513 **The effect of compression in the watercolor illusion**

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The water-color illusion consists of a chromatic darker wiggly contour, flanked by a lighter contour on a white background. It causes a long-range coloration effect across large areas, next to the brighter contour. The effect of coloration must be accomplished by two processes: a local process that causes spreading of the brighter contour to the region next to it, followed by a more global process that propagates the color over large areas. We examine the low-level computational processes of the first process and propose that the effect is due to data compression in the early stages of processing. We compare results, using computational compression against other operations that can give rise to smoothing --- Gaussian smoothing and anisotropic diffusion. The compression is implemented using a redundant wavelet system representation, with a smoothing, a first-order and a second-order difference kernel. Small components are disregarded and the image is reconstructed using the L0 norm. Comparative results on variations of the watercolor-illusion, with various colors, show that only compression can account for the spreading of the bright contour. Other methods will cause spreading of both dark and bright contours. Intuitively, the effect is explained as follows: Compression amounts to discarding some of the high-frequency components of small value. There are many more high-frequency components in a wiggly line than in a straight line, which explains the much stronger effect in the former. A single contour will not produce the effect, because all coefficients will have same magnitude. However, in the case of two contours of different contrast, the coefficients of the high-frequency components on the brighter edge are much smaller than the ones on the darker edge. Thus, they are reduced during compression, which in turn causes a smoothing next to the brighter edge.

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16.514 **Perception of a Positive Afterimage in Neon Color Spreading Displays**

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The perceived color of a region can be influenced by spectral properties of adjacent areas, resulting in simultaneous color contrast. Color perception also depends on the chromatic properties of prior stimulation, a phenomenon known as color adaptation. The latter effect can result in a negative afterimage whose spectral properties are complementary to the chromatic properties of the prior stimulus. A positive afterimage is a secondary phenomenon resulting either from chromatic induction of a negative afterimage or from a negative afterimage produced by simultaneous contrast or from both. It has been demonstrated that perception of a positive afterimage can be strengthened by placing a solid contour around the area where the afterimage is perceived (Daw, Nature, 1962). This study explores secondary induction effects that result in a positive afterimage in combination with a neon color spreading in a region enclosed by an illusory boundary. Our experiments investigate the chromatic properties of that region over the lifetime of the afterimage. Participants were asked to evaluate the color of a figure perceived after superimposition of a neon color diamond over a diamond figure induced by a chromatic surround. The duration of presentation of the neon figure was systematically varied in order to probe the time course of chromatic integration. Our results demonstrate that the presence of an illusory boundary enhances the effect of the positive afterimage. While the positive afterimage is being perceived, the color of the illusory figure changes as a function of both the color of the surround that induces the afterimage and the neon color of the figural area. Chromatic integration occurs along the “mixture line” between the color of the positive afterimage and the neon color of the illusory figure.

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16.515 **Connecting retinal and cortical processes to describe afterimage percepts**

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Afterimages have long been understood as visual experiences of past visual stimulation. Importantly, a large set of phenomenological evidence indicates that afterimages are not only based on past visual stimulation but also interact with present visual representations. Recent theoretical and empirical findings suggest that perceptual properties of afterimages strongly rely on the interactions of surface and boundary structures that derive from both past inducing stimuli and current stimuli. In some cases, observers experience afterimages that match with neither of the stimuli. The mixing of present and past stimulation suggests that afterimages are of great importance for investigating the human visual system, because they provide a means of revealing visual processes that cannot be invoked by a single stimulus. However, despite their potential importance, over a century of afterimage investigations have not come to a theoretical consensus on how afterimages are produced. Earlier hypotheses assumed that the adaptation of the retinal visual system generates afterimages, while later studies argued that cortical processing plays an important role in afterimage perception. We argue that, to use afterimages as a research tool, researchers need a better understanding of how afterimage percepts form. We start this process by reviewing key previous research that impacts afterimage theories, and we pay special attention to some neglected theoretic connections between the retinal and the cortical hypotheses. The main finding of our work indicates that the classic photopigment bleaching hypothesis has been significantly modified with a better understanding of functional retinal structures. However, this modification is often overlooked in recent literature that emphasizes cortical visual processing. Scrutiny of the afterimage literature implies that both retinal and cortical processes are likely to jointly produce afterimages and that afterimage formation cannot be completely understood based solely on either one of these processes.

16.516 **Predictions of a cortical model of induced visual fading**

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At last year’s VSS, Francis & Kim (2010) demonstrated that simulations of a cortical model of visual perception explained the large scale induced fading effects reported by Simons et al. (2006). The main model feature was that oriented boundary responses to luminance edges were subject to adaptation, and when the adaptation was substantial enough the weakened boundaries allowed color and brightness signals to spread across surfaces in a diffusive filling-in process. Changes in the image (such as the disappearance of high contrast dots or a global decrease in luminance) exacerbated these effects by introducing an orientation after-response among boundary representations. In new model simulations we explored this explanation by varying the duration of high contrast dots and measuring the amount of model-predicted fading. As the duration of the dots increased over several seconds, the model predicts stronger adaptation and more induced fading at dot offset. These predictions are in contrast to a possible alternative hypothesis that the transient signals at dot offset are critical for induced fading. Given the durations of the dots, this alternative explanation would not predict any difference because the transient offset responses should be equivalent. In further explorations of the model, we noted that the model suggests that there should be substantial variation in fading across the images used by Simons et al. (2006). Overall, the model both accounts for previous findings and suggests novel properties of induced fading that can be tested in future experiments. Because the model has previously been used to explain a wide variety of related phenomena (including afterimages and visual persistence), it seems that a relatively small set of mechanisms in visual cortex provide a unified explanation of disparate phenomena.

16.517 **Contrast adaptation reveals the contributions from chromatic channels tuned to intermediate directions of color space in the chromatic visual evoked potential**

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Prior research suggests the presence of higher order cortical chromatic channels that process colors along intermediate axes of color space, in addition to the LM and S opponent channels. The chromatic visual evoked poten-

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tial (crVEP) has been used to study color processing in basic, clinical, and developmental studies. Although the resistance of the crVEP to attentional modulation suggests that the crVEP reflects relatively low level responses, the level at which the crVEP reflects chromatic processing is unknown. Chromatic adaptation studies have revealed evidence for contributions from selective cardinal mechanisms in the crVEP. However, evidence for contribution from the intermediate channels has been less compelling. In the present study we employed chromatic contrast adaptation to test for the presence of input from intermediate channels in the crVEP. Amplitude changes of the CIII-CII pre- and post-adaptation waveform components were measured. The data were fit to ellipses in a cone-based color space and analyzed for interactive adaptation effects on orthogonal axes. The results indicate substantial contribution from intermediately tuned channels to the crVEP. These data suggest that the crVEP can be used to objectively and noninvasively investigate spatial and temporal characteristics of these higher-order channels and the role they play in cortical color processing.

16.518 **The illumination correction bias of the human visual system**

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Colour constancy is the ability of the human visual system to keep object colours roughly constant over changes in illumination. Colour constancy measurements are typically made for a limited number of illumination conditions, and often for simulated rather than real-world scenes. The generalisability of the results is therefore unclear. Here we measure colour constancy for a scene with real objects under a broad range of illuminations, both on and off the daylight locus. The setup consists of a spectrally tunable LED illuminator that emits diffuse, nearly uniform light into an enclosed box of approximately 42 x 60 x 75cm (hwd). Subjects viewed the interior of the box through a viewport, and adjusted the chromaticity of an LCD-display patch visible through a cut-out in the Mondrian paper lining the box, using a mobile black keypad reached through an armhole in the box front. Their task was to adjust the patch to appear grey, under each of eight distinct smooth broad-band test illuminations whose chromaticity coordinates spanned an ellipse in Lab space centred on daylight D65 (at distances 70 – 120 ΔE). Subjects initially dark adapted for 5 minutes. On each trial, subjects adapted to D65 for 10 seconds, followed by adaptation to the test illumination for 10 seconds during which they adjusted the patch chromaticity. The cycle repeated until the subject signalled a match to “grey”. On average, colour constancy was imperfect: the adjusted “grey” chromaticity deviated significantly from the illumination chromaticity, but was significantly better for test illumination chromaticities on the daylight locus. For test chromaticities off the daylight locus, errors were lower for “redder” and “yellower” test illuminations. Colour constancy thus varies across illuminations, and may be better adapted to “warm” illuminations.

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16.519 **Estimation of the** best illumination for commercial food counters

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The color rendering of lighting is typically evaluated by how natural the objects are perceived. The influence of the illumination on the aesthetics of the scenes is another important aspect to consider. However, predicting these aspects from existing quality indices for specific applications is difficult. We estimated, psychophysically, the best lighting for naturalness and preference for food displays in commercial environments. Fifteen images of commercial food counters of fruits, vegetables, meat, and fish were digitalized by a hyperspectral system in a supermarket. The scenes were simulated to be illuminated by illuminants synthesized from Judd’s daylight spectral basis functions for a grid of chromaticities on and around the Planckian locus with correlated color temperatures (CCT) ranging 2,222 – 20,000 K and were displayed on an LCD monitor controlled by a ViSaGe visual stimulus generator. Observers adjusted the chromaticity of the illuminant under two criteria: so that the scenes looked the most natural or the most pleasant. The mean CCT averaged over all the observers and images for the preference criterion was 5900 K and for the naturalness criterion was 7100 K. This type of pattern was consistently found for each scene category. In addition, it was found that the most preferred CCTs for fish and meat were considerably lower than those for fruits and vegetables. The average chromaticities for both criteria were below the locus that maximized the general color rendering index (CRI). The convex hull volume of the colors in the CIELAB space of the each scene illuminated by the most preferred illuminant was consistently larger than that for the most natural illuminant, indicating that the observers preferred lighting rendering more saturated colors. These results show that preference and naturalness require different illuminations and that the ideal spectrum may have to be tuned for different food classes.

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16.520 **Object Color Preferences**

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We investigated how object context influences color preferences by comparing preferences for “contextless” colored squares with preferences for colors of a variety of objects (e.g., walls, trim, couches, throw pillows, dress shirts/blouses, ties/scarves, and T-shirts). In Experiment 1 we found that hue preferences for contextless squares generalize relatively well to hue preferences for imagined objects, with substantial differences occurring in the saturation and lightness dimensions. In Experiments 2 and 3 we found that object color preferences are relatively invariant when the objects are (a) imagined to be the color that is presented as a small square, (b) depicted as colored images of objects, and (c) viewed as actual physical objects. In Experiment 4 we found that object color preferences are related to the degree to which colors help objects fulfill particular functions or outcomes. We also considered relations between our results and theories of color preference.

Acknowledgement: National Science Foundation

Color and light: High-level

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Vista Ballroom

16.521 **Color memory and perception for real illuminated objects**

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Purpose: The fidelity of color memory is controversial. Here we compared directly the bias and precision of color perception and memory for real objects. Method: Observers viewed 16 painted wooden cubes in two matte gray booths and made color matches by selecting the best-matching paint from a commercial booklet of 985 samples. The matching booklet was either under the same or different illumination as the cube and matches were made either simultaneously (Perception) or after a 15-minute delay (Memory). Each observer made matches for four cubes in each of the four conditions, and cubes were counterbalanced across conditions. Cube colors evenly sampled the chromaticity space defined by the 985 paint samples (u’v’ space). Results: 1. Bias: For each cube, we computed the average chromaticity of the paint samples chosen by observers in each condition. Bias was defined as the difference between average matches in perception and memory. A permutations test showed that few of the biases were significant. Furthermore, the size of observed biases is consistent with a simple ideal observer model that takes into account the discretization of the matching booklet and formulates memory as unbiased but less precise than perception. 2. Precision for each cube was the average Euclidean distance between each chosen paint sample and the average match (in u’v’) in that condition. Memory for cube colors was significantly less precise than was perception for the same colors ($p<0.05$). In addition, across cubes, significantly more paint samples were chosen in memory conditions than in perception conditions ($p<0.005$). The illumination condition had no effect on number of paint samples chosen ($p=0.45$). Conclusions: The data suggest that memory for real, illuminated cubes is less precise than perception. However, under these experimental conditions, memory is not systematically biased compared to perception.

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16.522 **Misbinding of color and motion in human V2**

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Wu, Kanai and Shimojo (Nature, 429:262, 2004) described a compelling illusion demonstrating a steady-state misbinding of color and motion. Here, we took advantage of the illusion and performed psychophysical and fMRI adaptation experiments to explore the neural mechanism of color-motion misbinding. The stimulus subtended 20°×14° of visual angle and contained two sheets of random dots, one sheet moving up and the other moving down. On the upward-moving sheet, dots in the right-end area (4°×14°) were red and the rest dots were green. On the downward-moving sheet, dots in the right-end area were green and the rest dots were red. When subjects fixated at the center of the stimulus, they bound the color and motion of the dots in the right-end area erroneously – the red dots appeared to move downwards and the green dots appeared to move upwards. In the psychophysical experiment, we measured the color-contingent motion aftereffect in the right-end area after adaptation to the illusory stimulus. A significant aftereffect was observed as if subjects had adapted to the perceived binding of color and motion, rather than the physical binding. For example, after adaptation, stationary red dots appeared to move upwards and stationary green dots appeared to move downwards. In the fMRI experiment, we measured direction-selective motion adaptation effects in V1, V2, V3, V4, V3A/B and V5. Relative to other cortical areas, V2 showed a much stronger adaptation effect to the perceived motion direction (rather than the physical direction) for both the red and green rots. Significantly, the fMRI adaptation effect in V2 correlated with the color contingent motion aftereffect across twelve subjects. This study provides the first human evidence that color and motion could be misbound at a very early stage of visual processing.

16.523 **The influence of central objects on peripheral color-binding errors**

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Peripheral visual objects may be perceived to have an illusory conjunction of features that is physically present in only the central visual field (Wu, Kanai & Shimojo, Nature 2004). Central objects play a role in initiating peripheral binding errors of motion and color but are not the sole source of the misbound motion features (Sun & Shevell, VSS 2010). The role of central objects in perceived peripheral color features remains an open question. RATIONALE: (a) Do color percepts of peripheral objects depend on whether the central stimulus is present? If so, then the central stimulus alters color binding of peripheral objects. (b) Can the perceived color of peripheral objects be a color physically present in only the central stimulus? If so, then the center contributes chromatic information to objects in the periphery. METHODS: The central stimulus was either (1) blank or (2) had red dots moving upward and green dots moving downward. The peripheral stimulus had (1) only white dots or (2) white and red dots. Upward- and downward-moving peripheral dots were always 50% each. The proportion of red dots among upward- and downward-moving peripheral dots was varied from 0% to 50%, with the rest white. Observers reported the colors of the majority of peripheral (1) upward-moving and (2) downward-moving dots. RESULTS: (i) The color percept of red in the periphery was enhanced or suppressed by the central stimulus, depending on whether the peripheral red dots moved in the same direction as the central red objects. (ii) Peripheral dots were never perceived to be red or green when all peripheral dots were white. (iii) Peripheral dots were never perceived to be green when green dots were present in only the center. CONCLUSION: The central stimuli alter color binding for peripheral objects but need not contribute a color feature perceived in the periphery.

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16.524 **Chromatic similarity affects color-motion binding errors**

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PURPOSE: Color-motion binding errors are well known, with peripheral upward moving dots of one color (e.g., red) perceived to move in the opposite direction (downward) when central dots of the same color move in the downward direction (Wu et al., 2004). This study investigated how chromatic similarity between central and peripheral stimuli affected color-motion binding errors. METHODS: A 28×22 deg stimulus had separate central and peripheral fields (similar to Wu et al., 2004). In the central field, half the dots moved in one vertical direction and had one color, and the other half moved in the opposite direction and had a different color (e.g., red dots moved upward and green dots downward). In the periphery, the moving dots were similar but with opposite directions (red downward, green upward). One chromaticity (green) was held constant in both center and periphery, and the other chromaticity (red) was constant in the center. The second chromaticity in the periphery was varied. Observers fixated in the center of the field, and responded by pressing pre-assigned buttons to report the perceived direction of the moving peripheral dots. The proportion of viewing time with a peripheral binding error was recorded during a 20 sec presentation period. RESULTS & CONCLUSIONS: When the color of the peripheral dots was the same as in the center (both red), the binding-error rate was high (similar to Wu et al., 2004). However, when the peripheral dots had other colors (e.g., orange or yellow), the binding-error rate declined as the similarity between central and peripheral chromaticities decreased. This reveals that the degree of chromatic similarity regulates color-motion binding errors.

Acknowledgement: NIH grant EY-04802

16.525 **Semantic Effects on Aesthetic Preference for Color Harmony in Visual Displays**

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Schloss and Palmer (2011) previously showed that people generally like harmonious color combinations consisting of colors that have the same or similar hue but differ in lightness in simple figure-ground displays (e.g., a light-blue square on a dark-blue square background). Are such preferences fixed or can they be altered by context due to different spatial/textural structure and/or different semantic features. Participants were shown visual displays that differed in the degree of harmony of the two component hues and the degree of harmony in the structure of the spatial array. They were shown pairs of displays and asked to indicate which they preferred. The semantic context was varied toward harmony or disharmony by presenting them as backgrounds for posters whose text was "Unity" or "Peace" versus "Chaos" or "Friction" in Experiment 1, and as album covers for new musical groups of the same names in Experiment 2. The results showed that preferences are indeed influenced by the meaning of the image. People liked harmonious color combinations more than disharmonious ones in harmonious contexts, but this difference disappeared in disharmonious contexts. This pattern of results is consistent with a general bias toward preferring harmonious color combinations that is modulated toward more harmony in harmonious contexts and toward less harmony in disharmonious contexts. Individual differences in preference for harmony (Griscom & Palmer VSS-2011) also influence the results.

Acknowledgement: NSF, Google

16.526 **Color Preference: Seasonal and Gender Differences**

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According to Palmer and Schloss's (2010) ecological theory of color aesthetics, people's preferences for colored objects influence their preferences for the colors associated with those objects. If so, broad changes in environmental colors (and any learned associations with them) might affect color preferences. The current study examined color preferences over the four seasons of the year at a college in New England, where there is substantial seasonal variation in the color of the outdoor environment. Thirty-nine participants who had lived in the area for at least six years rated their preferences on the 37 colors of the Berkeley Color Project, including eight chromatic hues at four "cuts" in color space (light, dark, saturated, and muted), and five achromatic colors (white, black, and three shades of gray), during the fall, winter, spring, and summer seasons. Seasonal changes in color preference were evident, particularly between ratings done in the spring and fall for colors characteristically associated with these seasons. Participants preferred dark warm colors more in the fall and light colors more in the spring. Substantial gender differences in color preference were also evident, with seasonal differences being more pronounced in males than females. These results are compared with recent theories and data about color preferences (e.g., Hurlbert & Ling, 2007; Schloss & Palmer, 2011).

16.527 **Effects of grouping on preference for color triplets**

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Schloss and Palmer (2011) found that people prefer color pairs that are harmonious, or similar in hue. In the present study, we investigated the relation between spatial composition and color harmony on preference for color triplets. Specifically, we tested whether people prefer similar colors to be closer together than contrasting colors. Participants indicated which of two simultaneously presented displays of color combinations they preferred. Each display contained three squares in a row, spaced such that the central square was closer to one of the flanking squares than the other. In one combination, the central square hue was similar to the closer square and contrasted with the farther square (e.g., a cyan flanking square being closer to a central green square and a red flanking square being farther). The other display had the same spacing, but the opposite color assignment of the flanking squares (e.g., a red flanking square being closer to a central green one and a cyan flanking square being farther). Participants chose the displays in which the similar colors were closer (i.e., congruent color-spatial grouping) more often than when the similar pairs were farther (i.e., incongruent color-spatial grouping). This effect was modulated by hue, however, in that the effect was stronger for differences in redness-greenness than in blueness-yellowness. Explanations will be considered in terms of (a) Berkeley school spirit (Schloss et. al, 2011), (b) visual discomfort, and (c) natural scene statistics (Juricevic et. al, 2011).

Acknowledgement: NSF

16.528 The Color of Musical Sounds: Color Associates of Harmony and Timbre in Non-Synesthetes

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Previous studies have shown that the tempo and harmonic mode (major vs. minor) of different pieces of classical music produce consistent cross-modal associations with dimensions of individual colors and that these associations are largely mediated by the shared emotional content of the colors and music (Schloss & Palmer, VSS-2008; Xu et al., VSS-2011; Palmer et al., VSS-2011). In the present study we extended this line of research by investigating cross-modal associations between two-color displays and musical sounds that varied in instrumental timbre and the harmonic structure of 2-note intervals and 3-note chords. The color stimuli consisted of color pairs chosen from the 37 colors of the Berkeley Color Project and the sound stimuli consisted of synthesized notes, two-note intervals, and three-note chords, using instrumental timbres derived from Grey's (1977) timbre space. Participants were asked to perform a 2AFC task to indicate which of two color pairs they felt was more strongly associated with the presented musical sound. They also rated the sound and the color pairs separately on each of five emotional dimensions (happy/sad, angry/clam, active/passive, strong/weak, and harmonious/disharmonious). The probability of choosing a given color pair was found to be strongly related to the fit between the degree of harmony of the musical sound and the difference in the degree of harmony between the two color pairs presented on that trial (i.e., harmonious color pairs were chosen to go with harmonious sounds and disharmonious color pairs to go with disharmonious sounds). Two dimensions of instrumental timbre – brightness (spectral centroid) and attack (rise time) – also showed systematic effects on participants' cross-modal choices of visual displays that differed in both color and spatial characteristics.

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16.529 Quantification of the Synesthetic Experience with the Visual Evoked Potential

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Synesthesia describes a condition wherein stimulus information of one type appears to produce sensations not normally associated with that stimulus. Experiencing particular colors when certain letters or numbers are viewed has been termed "color-grapheme synesthesia". Synesthesia is believed to influence perception at a relatively low level and result in altered levels of activation in the visual cortex, among other areas. The visual evoked potential (VEP) is uniquely suited to investigate plausible changes in activity levels in the visual cortex, which has proven useful in investigations into the integrity of the visual system. Coupled with a recent upsurge of Magnetic Resonance Imaging (MRI) research investigating the neural underpinnings of synesthesia, the VEP may help further the current body of literature by helping to quantify the synesthetic experience. Pattern reversal and onset/offset VEPs were recorded from controls and subjects with color-grapheme synesthesia. Synesthesia was self-reported but verified with an online testing battery (see synesthete.org) and synesthetes performed color matches to achromatic block letters and symbols. Inducing stimuli were constructed of randomly placed block letters which elicited strong synesthetic color fill-in as well as control symbols and letters that did not elicit colors. Control and matching stimuli were also presented with varied saturations of the matched chromaticity. Fourier and waveform components show differences between synesthetes and controls which indicate that the magnitude of the synesthetic percept can be quantified with the VEP.

16.530 Interactions between colour and synaesthetic colour: An effect of simultaneous colour contrast on synaesthetic colours

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We investigated whether simultaneous colour contrast affects the synaesthetic colour experience and normal colour percept in a similar manner. We simultaneously presented a target stimulus (i.e. graph- eme) and a reference stimulus (i.e. hash). Either the grapheme or the hash was presented on a saturated background of the same or opposite colour category as the synaesthetic colour and the other stimulus on a grey background. In both conditions, grapheme-colour synaesthetes were asked to colour the hash in a colour similar to the synaesthetic colour of the grapheme. Controls that were pair-matched to the synaesthetes performed the same experiment, but for them, the grapheme was presented in the colour induced by the grapheme in synaesthetes. When graphemes were presented on a grey and the hash on a coloured background, a traditional simultaneous colour-contrast effect was found for controls as well as synaesthetes. When graphemes were presented on colour and the hash on grey, the controls again showed a traditional simultaneous colour-contrast effect, whereas the synaesthetes showed the opposite effect. Our results show that synaesthetic colour experiences differ from normal colour perception; both are susceptible to different surrounding colours, but not in a comparable manner.

16.531 Patterns of neural activity associated with synesthetic color perception: a case study

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Grapheme-color synesthesia is a rare perceptual phenomenon in which graphemes are perceived to be inherently colored. Previous research suggests that grapheme-color synesthesia is related to the cross-activation of the visual word from area (VWFA) and V4 (Nunn et al., 2002; Hubbard & Ramachandran, 2005), but the functional significance of the early visual activity for synesthetic experience is not known. We investigated neural patterns underpinning grapheme-color synesthesia using fMRI and multi-voxel pattern classification (MVPC). We tested one grapheme-color synesthete on a battery of behavioral tasks and found the synesthete's performance consistent with a projector type. We then performed fMRI retinotopic mapping in the synesthete and four control subjects to localize early visual areas V1-V4. In a separate fMRI session, subjects viewed two color patches and two gray letters in separate blocks. The hue of the color patches matched the colors experienced by the synesthete for the selected letters. We used MVPC to decode different colors and letters (within category classification), and did not observe significant difference between the synesthete and controls. However, the synesthete showed significant higher classification accuracies in V1, V2, and V3 compared to controls in cross-category classification, (i.e., training a classifier on color data and decode letter data and vice versa). V4 showed an asymmetric effect: accuracy was higher in the synesthete than controls when the classifier was trained on letter data and tested on color data, but accuracy was similar for the synesthete and controls when the classifier was trained on color data and tested on letter data. Overall these results suggest that earlier visual areas like V1 may significantly contribute to the perceptual reality of synesthetic color perception in grapheme-color synesthesia.

Spatial vision: Mechanisms

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Vista Ballroom

16.532 fMRI of the magnocellular and parvocellular subdivisions of human LGN

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Parallel processing in the visual system is particularly well-defined in the lateral geniculate nucleus (LGN) of the thalamus, which has distinct anatomical subdivisions with complementary functional properties. In particular, the magnocellular subdivision of the LGN is selective for high temporal frequencies and low spatial frequencies, while the parvocellular subdivision is selective for low temporal frequencies, high spatial frequencies, and color. Despite their distinctive functional characteristics and critical position in the visual processing pathway from retina to cortex, the subdivisions of the LGN have rarely been studied in humans. Research has been limited by the difficulty of measuring neural responses from LGN subdivisions due to their small size and their location deep in the brain. We used high-resolution fMRI, combined with presentation of visual stimuli designed to differentially activate magnocellular and parvocellular neuronal responses, to functionally localize the magnocellular and parvocellular subdivisions in humans. Preliminary results suggest that specific combinations of spatial, temporal, luminance contrast, and chromatic stimulus factors selected to preferentially evoke BOLD responses in either magnocellular or parvocellular layers allow functional localization of these subdivisions. The ability to reliably localize the magnocellular and parvocellular subdivisions of the LGN in humans will facilitate investigations into the role of these specialized early visual pathways in human visual perception, attention, and cognition.

Acknowledgement: NSF Graduate Research Fellowship

16.533 Can principal component analysis reliably identify the temporal response of cortical area V1?

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The early CI component and its polarity inversion as a stimulus moves from inferior to superior visual field is the basis for many evoked response potential (ERP) based claims of attention and other perceptual effects involving V1 activation. However, recent results have undermined the validity those criteria. Ales et al. (2010) have shown "polarity inversion is an unreliable diagnostic for activity originating in striate cortex". The fact that the CI is the earliest response peak is also not indicative of a V1 signal since recent ERP source modeling demonstrate that the signals from V1 and V2 begin at about the same time (Ales et al, 2009). With historical ERP measures of V1 activation discredited, does any method offer reliable isolation of the striate cortex response besides inverse source modeling along with fMRI to constrain the solution space? Zhang and Hood (2004) suggested principal component analysis provides a means of deriving the V1 response when combined with multi-focal stimulation. The change in the first component signal strength with stimulus position was consistent with the cruciform model of V1. However, we now know the cruciform model is flawed, so we revisited the utility of using PCA to isolate V1. In two subjects, using high density multi-focal stimuli with a 96 electrode recording array we compared the V1 temporal response based on PCA verses inverse source modeling methods. The concordance between the V1 response derived from PCA and fMRI constrained inverse source modeling was high. However, in 21 subjects, simulated ERPs using boundary element forward models and fMRI based source positions corresponding to a 96 patch multi-focal stimulus demonstrated that the first PCA component of simulated ERP's do not always match the V1 source time functions. In conclusion, PCA of the multi-focal ERP does not provide a reliable estimate of an individual's V1 response.

Acknowledgement: NSF

16.534 A novel shape illusion predicted by the effect of local orientation on retinotopic-scale V1 population responses

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Population responses to visual stimuli in the primate primary visual cortex are topographically organized at multiple spatial scales, each of which may be useful for a subset of visual judgments. At a fine scale, these responses are organized into orientation columns; signals at this scale might be useful for discriminating between different textures. At a larger (retinotopic) scale, the population responses seem to encode the contrast envelope of visual stimuli; signals at this scale might be useful for computing global shape. Are responses at this larger scale independent of the local orientation structure of the stimulus? To answer this question, we used voltage-sensitive dye imaging in fixating monkeys to measure V1 population responses to small isolated Gabor patches with a fixed contrast envelope and varying carrier orientations. We found that V1 response at the retinotopic scale is significantly elongated along the direction corresponding to the orientation of the carrier. Moreover, increasing the carrier frequency reduces this effect. Both of these results can be explained by an elongation of the V1 population receptive field along the preferred orientation, similar to findings in single V1 neurons. If we rely on these retinotopic-scale V1 population responses when making judgments about global shape, the results above suggest that local orientation might bias these judgments. We tested this prediction in a psychophysical task by having human subjects determine which of two small patches was more circular. Consistent with the physiological results, we found that human subjects perceive Gabor patches to be elongated along the orientation of the sinusoidal carrier, and that increasing the carrier frequency reduces this effect. Taken together, these results suggest that we make use of information from the retinotopic scale of V1 population responses when determining shape, and that for small stimuli, local orientation information can bias our perception of global shape.

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16.535 Reconstructing spatial maps in occipital, parietal and frontal cortex using an encoding model of spatial receptive fields

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Most methods for assessing the spatial selectivity of visual areas using fMRI employ periodic stimuli and rely on well-preserved retinotopy. However, it is possible that a population code across a region might reliably represent the spatial position of a stimulus, even in the absence of strong retinotopic organization. Here, we used a forward encoding model which provides an estimate of the BOLD response of hypothesized information channels, modeled here as 2D spatial receptive fields, to evaluate spatial coding across occipital, parietal, and frontal regions. Observers viewed flickering checkerboards presented at different locations on the screen. We then reconstructed the visual stimulus viewed by each observer using the BOLD signal in each independently localized area. We could produce stable and robust reconstructions from responses in occipital visual areas, posterior IPS, and human MT (hMT+). These reconstructions are shown to be reproducible across sessions and are generalizable to untrained stimuli, and regions known to have larger receptive fields are shown to have coarser visual field reconstructions. The fidelity of reconstructions achieved with this model, which uses significantly fewer information channels than many others (Nishimoto et al, 2011), allows for swift data acquisition and supports the measurement of spatial maps across different task demands using identical stimuli. This technique can be used to probe models of information coding across cortical regions and to ask novel questions about the dynamic neural mechanisms of cognitive processes, like visual attention.

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16.536 An improved method for mapping neuronal receptive fields in prefrontal cortex

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The frontal eye field (FEF) is a region of prefrontal cortex that plays an important role in vision and eye movements. Single neurons in FEF are responsive to stimuli in specific regions of visual space known as the receptive field (RF). Despite their importance, FEF RF properties have seldom been systematically measured. Additionally, RF properties can change over time. For example, around the time of eye movements RFs can move predictively based on the impending saccade direction. These peri-saccadic RFs have been shown to "jump" in FEF and "expand" in visuomotor area LIP. In the absence of eye movements, similar shifting phenomena have been observed because of changes in the focus of attention. Given the ubiquity of eye movements and shifts of attention in our daily lives, changes in RFs may be frequent and dramatic. However, conventional RF mapping protocols are limited in their ability to capture the dynamic nature of RFs. RFs are generally measured outside the context of the central experimental manipulation in greatly simplified paradigms. Such RF measures tacitly assume that RFs remain stable across conditions and attentional states. We developed a more direct measure of FEF RF dynamics. We used a slower frame rate version of "spike-triggered averaging" (STA), a technique established to measure RFs in primary visual cortex. Stimuli consisted of white dots on a black background, presented sequentially and pseudorandomly at variable locations while the monkey maintained fixation. STA estimates of RF centers and sizes matched those determined by a more conventional approach using a series of stimuli regularly spaced over fixed directions and amplitudes. We used a range of framerates to measure the temporal sensitivity of FEF neurons. Our findings validate the STA method of RF mapping in prefrontal cortex and provide greater insight into the role of FEF in visual perception.

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16.537 **Effect of contrast polarity and target separation on vernier performance with luminance and chromatic contrast**

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Hyperacuity performance deteriorates if targets are of opposite polarity. With grating pairs of mixed luminance and chromatic contrast, matched or unmatched in polarity, we have previously reported (Sun et al., 2005) luminance contrast polarity to determine hyperacuity thresholds, except close to isoluminance, when chromatic contrast polarity becomes important. This suggests both luminance and chromatic mechanisms compete for access to vernier mechanisms We expand these data and further investigate these mechanisms using target separation. With increasing target separation, contrast polarity effects on vernier are lost (thresholds become similar), which has been interpreted such that, with matched contrast polarity, vernier thresholds are determined with a linear filter operation, and with opposite contrast polarity local signs are used (Waugh & Levi, 1993). If luminance and chromatic mechanisms both access hyperacuity mechanisms, the interaction of target separation and contrast polarity should be the same for luminance and chromatic gratings. Psychophysical hyperacuity thresholds for sine-wave grating pairs of the same or opposite polarities for both luminance and chromatic conditions were measured as a function of target separation. Additionally, blue-yellow gratings were used with a deuteranopic observer to investigate hyperacuity performance based on S cones. We also related these results to physiological responses of macaque retinal ganglion cells. Thresholds for both luminance and chromatic gratings showed the same interaction with target separation and contrast polarity; for abutting targets thresholds were higher with targets of mixed polarity but when separated (ca. 1 deg) contrast polarity made no difference. We were able to discount other spatial cues (e.g., 2F chromatic response of MC cells) as contributing to hyperacuity with chromatic gratings. We interpret the results as evidence that both chromatic and luminance postreceptoral mechanisms have direct access to vernier mechanisms.

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16.538 **Fixational eye movements predict the discrepancy between behavioral and neurophysiological measurements of contrast sensitivity**

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The response characteristics of neurons in the early visual system are often studied in anesthetized animals, under conditions in which their eyes are paralyzed. Contrast sensitivity functions of neurons measured in these conditions deviate significantly from behavioral measurements of contrast sensitivity -- psychophysical measurements peak at higher spatial frequencies and exhibit stronger low-frequency suppression than their neurophysiological counterparts. One possible basis for the discrepancy is lack of consideration of the effect of abolishing eye movements in neurophysiological recordings. Microscopic eye movements are always present during natural fixation, and they have been shown to enhance high spatial frequency vision. Here, we examine how neuronal response properties determined in the absence of retinal image motion apply to natural viewing conditions. We describe an "equivalent filter" for retinal ganglion cells which combines measures of neural responses determined with an immobile stimulus and the statistics of human fixational eye movements. We show that consideration of fixational eye movements eliminates the discrepancy between psychophysical and neurophysiological measurements. For both P and M cells at all the considered visual eccentricities, neuronal sensitivity to time-varying inputs shifts towards higher spatial frequencies when the influence of fixational eye movements is taken into account. Thus, our model predicts that contrast sensitivity functions measured with paralyzed eyes significantly underestimate the actual sensitivity to high spatial frequencies present in natural viewing conditions.

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16.539 **The spatial tuning of perceptual serial dependence**

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How does the visual system achieve stable and continuous perception despite the often noisy and ever-changing input it receives? We previously reported (Fischer, Shankey, & Whitney, VSS, 2011) on a newly discovered mechanism that may aid in perceptual stability: visual perception is serially dependent, reflecting an integration of input over the last ten seconds or more. Serial dependence is potentially an efficient means of achieving perceptual continuity over time, but to be useful for tasks like tracking objects and planning saccades, it should be spatially tuned, occurring more strongly within a location in space than across different locations. Whether or how serial dependence is spatially tuned is not yet known. Here, we tested for spatial specificity of serial dependence using an orientation judgment task. Subjects saw a series of Gabor patches with random orientations, separated in time by an average of 5 seconds each, and adjusted a response bar to report the perceived orientation of the Gabor on each trial. For any given pair of successive trials, the Gabors could be in i) the same retinal and spatial (screen-centered) location, ii) the same retinal, but different spatial locations, iii) the same spatial, but different retinal locations, or iv) different retinal and spatial locations. These conditions allowed for two key contrasts reflecting the unique effects of changes in retinotopic and spatiotopic coordinates. We quantified serial dependence as the degree to which errors in subjects' orientation judgments were biased toward the orientation seen on the previous trial. We found that serial dependence is strongly position tuned, and this tuning is carried mostly by retinotopic selectivity. However, there was a unique and significant selectivity for spatiotopic position as well. These results support the potential function of serial dependence in maintaining stable representations of objects over time.

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16.540 **Contrast gain control alone is not enough in mid-level discrimination tasks**.

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Overlaid masks of very different spatial frequency or orientation can disrupt fine pattern discriminations. Lateral or surround masks can produce similar disruptions in performance. The effects have both been modeled as pooled divisive contrast gain control, but it is not clear a) whether the processes are identical in the overlaid and lateral conditions, or b) whether response gain control is involved as well as contrast gain control. We measured contrast response functions to evaluate whether curves shifted horizontally (contrast gain) or vertically (response gain) in the presence of masks. Observers viewed one of a pair of at-or near vertical 15 cpd sinusoidal gratings on each trial of a session, upon which spatial frequency or orientation discriminations were made in different sessions. Also in different sessions, masks were either overlaid or positioned as an annulus, and were presented either at 2% or 25% contrast. The orientation and spatial frequency of the mask depended upon both the task and the spatial configuration and was chosen because significant masking had been previously observed in the chosen conditions. Within each session, target contrast was randomly varied in equal linear steps from 3.1% contrast to 25% contrast (3.1%, 6.3%, 9.4%, 12.5%, 15.6%, 18.8%, 21.9%, and 25%) to generate contrast response functions. We fit Naka-Rushton functions to the data, with parameters C50 and Rmax free to vary. The functions accounted for the data well, and no significant differences were found between overlaid and surround masks, nor between judgment types. There was no contribution of contrast gain in the 2% mask conditions, but at the higher mask contrast, combined contributions from both types of gain were required.

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16.541 **Dynamics of unconscious contextual effects in orientation processing**

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Introduction: Contextual effects abound in the real world. A classic example of this is the tilt illusion that results in a target's orientation appearing repelled from that of the surround. However the opposite effect can also occur (the indirect tilt illusion) and the target's orientation appears shifted towards that of the surround. These orientation biases have revealed much about the underlying detectors involved in visual processing (low-level effects) but what remains at stake is the role of higher-level cognitive influences. Specifically, it is widely believed that the indirect tilt illusion requires additional input from higher cortical areas where the stimulus is consciously encoded. Methods We designed a novel reverse correlation technique to investigate this. The stimulus consisted of a concentric annular surround (outer diameter 7.8°) containing a 2cpd grating that could have one of 12 possible orientations abutting a circular patch (diameter 1.8°) where a vertical 2cpd grating was presented every 2 seconds. The surround was refreshed on each frame (11.7ms) and each orientation had an equal probability of being selected. The observers' (n=5) task was to report after each target presentation whether it had appeared tilted clockwise (CW) or counterclockwise (CCW) of a subjective vertical. Results All observers displayed a strong direct tilt illusion with this technique. In the majority of the observers (n=4) we also obtain a robust indirect tilt illusion. Both illusions occur reliably and over a similar time course (roughly ± 60ms around the time of target presentation) despite the lack of conscious access to the surround orientation. Conclusion: These results support the role of a single mechanism underlying orientation biases and refute the need for higher-level conscious processing of the context.

Acknowledgement: Australian Centre of Excellence in Vision Science

16.542 **Orientation adaptation without plasticity**

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Orientation selectivity is a key characteristic of visual cortical neurons and it is first exhibited in primary visual cortex. This selectivity is not a static property of cortical neurons, but rather depends on the recent stimulus history. In particular, even a brief exposure to an oriented stimulus is known to result in shifts of orientation tuning curves. These shifts are typically interpreted as signs of short-term plasticity in primary visual cortex. This interpretation, however, ignores that visual cortical cells are part of a dynamical system with recurrent connections through which information on stimulus history becomes embedded in the neural response. We investigated whether these dynamics can explain the reported adaptation effects. Methods: We implemented a network model of orientation selectivity based on recurrent lateral interactions to study the temporal dynamics of orientation tuning and its dependence on stimulus history. Results: When presented with pairs of gratings, the model replicated the shifts in tuning curves that have been observed experimentally. No changes in model parameters or addition of new parameters were necessary to obtain these shifts; rather, they emerged naturally as a consequence of the network not reaching its steady state response during the rapid presentation of multiple stimuli. Conclusion: This finding has important implications for the interpretation of changes in neural responses that depend on recent history; our simulations show that such changes need not involve any plasticity and could be caused by neural population dynamics, which are slow due to the recurrent connections. These implications are not limited to the orientation tuning networks of V1 but extend to any recurrently connected neural network.

16.543 **Orientation Tuning in Schizophrenia Measured Using Reverse Correlation Psychophysics**

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Selectivity for visual stimulus orientation is observed in neurons within primary visual cortex (V1), and it is believed that feed-forward orientation tuning is shaped by both excitatory and inhibitory input. It has been recently demonstrated that for healthy adults, performance on an orientation discrimination task correlated with GABA concentrations in early visual cortex as measured by magnetic resonance spectroscopy. In schizophrenia, visual processing abnormalities have been observed that are consistent with dysfunctional GABAergic inhibition in visual cortex. Therefore, we were interested in examining how such ostensibly abnormal inhibition may affect orientation tuning in this disorder. We used the reverse correlation method of Ringach (1997, Vis. Res., 7, p. 963) to measure the ability of subjects with schizophrenia and healthy adults to detect vertically or horizontally oriented targets in a rapidly changing series of oriented grating stimuli. By calculating the distribution of orientations presented prior to each response, reaction times were estimated and the probability of responding to each of the ten stimulus orientations was measured. These probability distributions strongly resembled the orientation tuning curves of individual V1 neurons, as measured by electrophysiology in macaques. Data from each group were fit with a difference-of-von Mises function, yielding a positive and a negative component for each fit. For both groups, negative components were broader than positive components, demonstrating reduction below baseline of responses to orientations near the target. This result is consistent with the idea of sharpening orientation selectivity via broadly tuned inhibition, which suppresses responses to orientations near the target. Between groups, preliminary results indicate significantly narrower positive components in schizophrenia, consistent with sharper orientation tuning in this disorder. This may be evidence of a compensatory mechanism whereby orientation tuning sharpens for patients with schizophrenia, which may be related to known weaker contextual modulation effects.

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16.544 **Side-inhibition, but not end-inhibition properties of neurons in areas MT and DM are related to the contrast sensitivity**

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The middle temporal (MT) and dorsomedial (DM) areas are densely myelinated subdivisions of extrastriate cortex which receive direct projections from V1. MT is characterised by strong direction selectivity and DM neurons are narrowly tuned for orientation. It has been established that visual cortical receptive fields in V1 and MT show more extensive spatial summation at lower contrasts, and that surround inhibition is more prominent at higher contrasts. We examined the responses of 129 MT neurons and 79 DM neurons in marmoset monkeys anaesthetised with sufentanil (6mg.kg-1.hr-1) and N2O (70% in O2). Stimuli were drifting sinewave gratings of optimal orientation, presented at optimal direction of motion within rectangular windows at 66% contrast. Lengths and widths of gratings (the latter being the dimension parallel to the direction of motion) were varied independently. Stimuli of near optimal dimensions were then presented at a range of contrasts. In MT, cells that showed peak responses upon presentation of wide gratings were less sensitive to low contrasts ($r=0.29$, $p<0.005$), while cells showing significant side-inhibition were more sensitive to low contrasts ($p<0.0001$). Similarly, in DM, cells that preferred narrow gratings were more sensitive to low contrasts ($r=0.33$, $p=0.003$), and those that preferred wide gratings (i.e. showing little or no side-inhibition) were less sensitive to low contrasts ($p<0.001$). The contrast sensitivity of neurons in both areas was not related to the preferred grating length, or strength of end-inhibition. In summary, in both areas the relationship between summation field size and contrast is more obviously expressed along the width dimension of receptive fields. The common pattern of response in these

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extrastriate areas, which have otherwise very different response properties, suggest a common biological implementation in the form of a generalized cortical circuit, or computations performed at a common source of inputs.

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16.545 **Psychophysical Assessment of Contrast Adaptation in the Magnocellular Pathway**

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The functional characteristics of cell populations within the parvo-, magno-, and koniocellular streams have been relatively well characterised in the retina and the lateral geniculate nucleus (LGN) using electrophysiological techniques in animal models. Yet, despite considerable effort, the difficulty in clear-cut assignment of functions to specific neuronal populations impedes the construction of stimuli that specifically affect one pathway in humans. Here, we present results from a novel psychophysical procedure that selectively manipulates magnocellular functioning and not other types of relay neurons within the dorsal LGN. We constructed an adaptation procedure based on the results of recent electrophysiolocial work and classical lesioning studies. The adaptation stimulus used in this procedure has been shown to specifically and profoundly affect the magnocellular pathway in primate LGN with little or no effect on response functions of parvo- and koniocellular populations. Furthermore, the specific spatiotemporal characteristics of this stimulus in combination with monocular adaptation eliminated or minimised any adaptation of cortical cells. We adapted one eye at a time and assessed the effects of this procedure by comparing contrast perception in the observer's adapted eye with that in the unadapted eye. We used test stimuli that have been shown to rely either on an intact parvo- or magnocellular pathway in primates. The results were consistent with altered responses of the magnocellular LGN layers following exposure to the spatiotemporal characteristics of our adaptation stimulus with no effect on parvocellular functioning. This finding indicates that adaptation of the magnocellular stream affects superthreshold appearance demonstrating its importance to a wide range of perceptual phenomena. We consider the functional significance of contrast adaptation in the magnocellular pathway and discuss the potential of this novel procedure to assess magnocellular contributions to perception in healthy and clinical populations.

Acknowledgement: Wellcome Trust

16.546 **Is γ-band activity different in primary visual cortex of awake and anesthetized states**

Dajun Xing[1](dx204@nyu.edu), Yutai Shen[2], Samuel Burns[1], Chun-I Yeh[1], Robert Shapley[1], Wu Li[2]; [1]Center for Neural Science, New York University, [2]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University

Gamma-band (25-90Hz) activity in the local field potentials (LFPs), EEG and MEG is present throughout the cerebral cortex and has been linked to many cognitive functions and mental disorders. It has been hypothesized that gamma activity, as a clock or stop watch signal, plays important roles in perception, attention and memory, which apparently require consciousness, by synchronizing signals in different cortical regions. However, gamma activity can also be found in the brains of anesthetized animals or even in brain slices, which most people would agree lack consciousness. To understand the role of gamma-band activity, we looked for differences in gamma-band activity generated in different cortical states. We characterized the frequency of the gamma peak and the durations of oscillatory epochs using time-frequency analysis of the LFP recorded in the primary visual cortex (V1) of awake and anesthetized macaques. We found that while the frequency at the peak of gamma activity in awake (~60Hz) was significantly higher than in anesthetized (~40Hz) monkeys, gamma-band bursts were not significantly different in awake and anesthetized – in both states the bursts resembled filtered broad-band noise: brief in time and variable in frequency. Such randomness of gamma dynamics can be explained by a cortical model: a recurrent network driven by Poisson noise. The model accounts for the upwards shift of peak gamma frequency in the awake cortex by a change of network parameters. We conclude that gamma activity in V1 is too random to act as a 'clock' or 'stop watch' in the perceptual or cognitive functions that have been proposed. Instead gamma band activity may be an epiphenomenon and its function needs to be re-evaluated.

Acknowledgement: This work was supported by NIH-EY001472, NSF-0745253, the Swartz Foundation, and National Basic Research Program of China Grant 2011CBA00400

16.547 **Superiority of angle discrimination to orientation discrimination for bisecting lines**

peter zaenen[1](peter.zaenen@ppw.kuleuven.be), robbe goris[2]; [1]Katholieke Universiteit Leuven, [2]New York University

We understand in some detail how early visual mechanisms encode local oriented features, but comparatively little is known about the subsequent integration of this fragmentary information. One suggestion that has attracted some attention proposes the existence of a mechanism that extracts angle information in a manner that defeats the laws of statistically optimal combination of independent orientation estimates. However, the existing psychophysical evidence is conflicting and inconclusive. One major limitation of all previous studies on angle discrimination is their reliance on the direct comparison of angle sensitivity with orientation sensitivity for the angle-components presented in isolation. This is problematic because orientation-selective signals are likely to be modified by the presence of the second angle-component. We compared angle sensitivity with orientation sensitivity for the same stimuli, composed of two bisecting lines. Observers were asked to detect either a change in stimulus angle (the component lines are rotated in opposite directions) or a change in stimulus orientation (the component lines are rotated in the same direction). The summed absolute differences in line orientation between the reference and target stimulus is identical in these tasks. If perceptual judgments are based on the optimal combination of line orientation estimates, sensitivity will be identical. This is not what we find. Angle discrimination is consistently better than orientation discrimination. In a control experiment, we show that this superior performance cannot be explained in terms of correlated noise of orientation-selective signals. Together, these findings suggest that the visual system either contains mechanisms selective for angle size, or, alternatively, manages to extract information from orientation-selective mechanisms that is uniquely available in angle discrimination tasks.

Spatial vision: Eccentricity, flankers, and texture

Friday, May 11, 6:45 - 9:30 pm

Poster Session, Vista Ballroom

16.548 **Pre-cortical noise shapes visual performance fields**

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Goals: Visual performance varies at isoeccentric locations. Discriminability is higher along the horizontal than the vertical meridian, and along the lower than the upper vertical meridian (e.g., Carrasco, Talgar & Cameron, 2001). This pattern of asymmetries is referred to as a "performance field." Performance is often limited by internal noise, which is considered to be independent of task, reflecting neuronal properties such as their density, gain, and physiological thresholds (Pelli & Farell, 1999). Internal noise arises from pre-cortical and cortical sources, which are reflected in monocular and binocular noise measurements, respectively (Raghavan, 1995). Here, we measure internal noise as a function of isoeccentric position, monocularly and binocularly, allowing us to identify the source of the noise that shapes performance fields. Methods: Observers performed a discrimination task at four locations (North, South, East & West; 5.5º eccentricity), with target contrast controlled by an adaptive staircase. All stimuli were presented stereoscopically with noise that was uncorrelated across both eyes. We measured thresholds monocularly and binocularly, in high (27%) and low (0%) contrast noise. By assessing threshold elevation as a function of external noise, we estimated the internal noise for each location and viewing condition. Results: We observed the classic shape of performance fields: better performance along the horizontal than the vertical meridian, and along the lower than the upper vertical meridian, under both monocular and binocular conditions. At each location, the monocular and binocular levels of internal noise were similar; binocular integration added no net noise. Thus, the noise that shapes visual performance fields is monocular and, therefore, pre-cortical. That noise may reflect differences in cell density at the level of the retinal ganglion cells and the LGN (e.g., Connolly & Van Essen, 1984; Curcio & Allen, 1990). Our findings indicate that performance fields result from early signal processing stages.

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16.549 **Contour enhancement benefits peripheral vision task for older adults**

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Age-related macular degeneration (AMD) is the leading cause of vision loss and blindness among Americans over the age of 65. As there is currently no effective medical treatment that can reverse the central vision loss associated with AMD, digital image-processing methods have been developed to improve image visibility in the periphery, but both the selection and efficacy of such methods are currently very limited. Progress has been limited for two reasons: the types of image enhancement that benefit peripheral vision are not well understood, and efficient methods for testing such benefits have been elusive. The goal of the current study has been to simultaneously develop both an effective new image-enhancement technique for peripheral vision, and an efficient means for validating the technique. We used a novel image statistics based contour detection algorithm to locate shape-defining edges in a scene, and then enhanced the scene by locally boosting image contrast along such edges. Using a gaze-contingent display, we tested normally sighted individuals with simulated central vision loss. Visual-search performance was measured as a function of contour enhancement strength (unprocessed, "medium", and "high" enhancement). A separate group of subjects subjectively judged which image in a pair "would lead to better search performance". We found that while contour enhancement had no significant effect on response time and accuracy in younger adults (ages 18-30), the medium contour enhancement led to significantly faster search times in older adults (ages 58-88). Both age groups subjectively preferred images with medium enhancement over the unprocessed originals or the high enhancement condition. Furthermore, across age groups and enhancement levels, we found a robust relationship between preference and performance, suggesting the task-specific preference can be an efficient surrogate for performance testing. For older adults, our findings also demonstrate a beneficial role of contour enhancement for peripheral vision.

Acknowledgement: NIH grant R01EY016093

16.550 **topological dominance in peripheral vision**

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Previous studies have shown that the speed of visual processing increases with eccentricity (Carrasco, 2002). Meanwhile, studies have demonstrated that the visual system is sensitive to topological changes, such as the appearance and disappearance of holes in a figure (Chen, 1982, 2005). Our results of a series of behavioral experiments suggest that, compare to foveal vision, the peripheral vision is more engaged in the rapid detection of topological changes. First, we employed a change detection paradigm to study the sensitivities to changes in foveal and peripheral vision. In each trial, a four-figure stimulus in continuous vertical motion was simultaneously and bilaterally presented at visual angle of 5°and 20°in each side. One of the four figures underwent an abrupt shape change either with a change of hole number ("HC") or without ("nHC"). The luminance contrast between stimuli and background was manipulated to avoid the ceiling effect. Moreover, in 11 experiments, many local features (e.g. luminance, similarity, spatial frequency, perimeter and shape of the contour) and task difficulty were well controlled, and the possibility that a "Hole" figure stimulates an on-center cell was ruled out. The detection performance was quantified as d'. The results showed that the d' under the "HC" condition was significantly higher in the periphery than it in the foveal, whereas the "nHC" condition manifested significantly higher d' in foveal than in periphery. And we also investigated the performance of change detection with a random motion paradigm. The topological advantage was still found in the periphery. Last, measuring at more eccentricities, the performance of "HC" retained its sensitivity while "nHC" deteriorated with eccentricity increased. The observed sensitivity advantage in periphery supports the view that topological definition of objects provides a coherent account for the object perception in the peripheral vision.

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16.551 **Centre-surround interactions on apparent contrast endure with broad-band stimuli**

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When a narrow-band target is presented at the fovea and is flanked by a stimulus with the same spatial characteristics, its apparent contrast is reduced by ~40%. This effect is tuned to orientation and spatial frequency (about one octave). Our objective was to verify whether increasing stimulus complexity (by using broad-band gratings) affects this well-known contrast induction phenomenon (i.e., do suppressive interactions persist when multiple spatial and orientation channels are solicited). The stimuli consisted of cosine luminance gratings that contained multiple spatial frequencies or orientations. The central target had a diameter of 1 deg and the surround a diameter of 6 deg. Contrast was set at 40% for all patterns and all conditions. We used a contrast-matching paradigm that consisted of a two-alternative TFC procedure and the method of constant stimuli. We found that the apparent contrast of a single grating target remains equally reduced (~40% reduction) when the compound surround includes gratings that have a spatial frequency within 0.5 octave and an orientation within 15 deg of the target in addition to a grating with the same characteristics as the target. However, suppression in the apparent contrast of the target is reduced by half (~23 %) when the compound surround includes gratings that have a spatial frequency beyond 1.0 octave and an orientation beyond 30 deg of the target in addition to a grating with the same characteristics as the target. Finally, when the same compound grating is presented in the centre and surround, regardless of the spatial frequencies and orientations included, maximum suppression occurs (~38%). Therefore, suppressive interactions are not a narrow-band or single channel phenomenon, but also occur under a visual context that includes multiple spatial frequencies and orientations.

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16.552 **Local image statistics have a perceptual metric that is nearly Euclidean**

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Natural scenes have an intricate statistical structure, including correlations of low and high orders that covary in a complex way. Thus, while the function of the visual system is best understood in the context of its natural inputs, it can be difficult to move from experiments that study responses to naturalistic inputs, to computational models that analyze how these responses arise. This motivated us to develop stimulus sets that abstract the statistics in natural scenes, and enable testing their effects individually and in combination. To reduce the dimensionality of the problem, we focus on binarized images. Following the findings of Tkacik et al. (2010), we restrict consideration to configurations of pixels in 2x2 neighborhoods, as this typifies the informative local image statistics. The 16 possible configurations within these neighborhoods are completely described by 10 image statistics, which thus form the coordinates of a perceptual space. We use a 4-AFC segmentation task to characterize human visual sensitivity to these 10 image statistics, alone and in combination. Results show that sensitivity to individual statistics is highly consistent across N=12 subjects (including naïve and experienced observers), as is sensitivity to pairwise interactions (N=6). In 4 subjects, we determined the perceptual metric in the entire 10-dimensional space. The metric is very close (~5% RMSE) to Euclidean. Moreover, the deviations from a Euclidean metric, though small, are conserved across subjects. These deviations are of two types: (i) an asymmetry between sensitivity to positive and negative variations of even-order statistics, and (ii) a unique interaction between specific pairwise statistics. (i) may reflect interactions across spatial scale, and (ii) may reflect a special role for corners. In sum, the informative statistics of natural images map out an orderly perceptual space, with simple, conserved rules for how individual statistics of low and high order combine.

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16.553 **Effects of flankers and attention on early visual adaptation**

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Introduction. Crowding refers to the detrimental effects of flankers on target identification. How early in visual processing does the effects of flankers start? Bi et al. (2009, J. Vis., 9(11):13, 1-10) found that crowding of the peripheral adaptor ceased to affect early visual adaptation when their observers' attention was controlled by a concurrent central task. Here we investigated the effects of flankers on early visual adaptation measured by threshold elevation aftereffect (TEAE) when the availability of attention for the peripheral task was manipulated. Methods. Three normally sighted observers performed a 2-interval-forced-choice task detecting a target sine-wave grating (2 c/deg, 2.5° diameter, ±45° tilt) presented at 10° eccentricity in the upper visual field. In each trial, an adaptor (4x contrast threshold) was presented at the same peripheral location as the target for 5 s before target presentation. Contrast thresholds with and without adaptation were measured to calculate threshold elevation. TEAEs both when the adaptor was presented alone and when it was surrounded by four high contrast flankers (8x contrast threshold; 2.7° center-to-center distance) were studied. In addition to the peripheral task, a stream of crosses (141 ms/item presentation rate) with different colors and orientations was presented at fixation during the adaptation phase. Attention available to the peripheral task was manipulated by varying the task demand at fixation (attend to color only or to the conjunction of color and orientation). Results. TEAE was significantly weakened (p <.05) by the presence of flankers irrespective of attention availability. Main effect of attention and flanker-by-attention interaction effect were not statistically significant. Conclusion. Flanker interference reduced the strength of early visual adaptation, regardless of the availability of attention to the peripheral task. Our findings are consistent with the notion that flanker interference starts early in visual processing at the site of orientation adaptation.

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16.554 **Collinear facilitation by flankers with invisible orientation**

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The detectability of a Gabor patch (target) in the fovea is improved by two high contrast, aligned, flanking Gabor patches (flankers). This effect is termed collinear facilitation (Polat & Sagi, 1993). Despite a lot of psychophysical and physiological studies about the characteristics of this facilitation, the processing stage that is responsible for this facilitation has not been identified. In this study, we psychophysically approached to the mechanism of collinear facilitation by investigating the influence of the orientation information and perceptual appearance of the flankers. For this purpose, we used D2 patterns (Motoyoshi & Nishida, 2001). The D2 pattern has specific orientation, and linear summation of two orthogonal D2 patterns is equal to an isotropic Laplacian. This means we can test conditions in which flankers contain orientation information that is consciously invisible. The target was a vertical D2 pattern, and two flankers were presented above and below the target, so facilitation should occur when the flankers were vertical. We measured the detection threshold of the target by two-interval forced choice. Three flanker types were tested: a vertical D2 pattern, a horizontal D2 pattern, and an isotropic Laplacian. The facilitation effect was greatest with the vertical D2 flankers, as expected. To our surprise, a smaller but robust facilitation also occurred with the isotropic Laplacian flankers. Facilitation did not occur with the horizontal D2 flankers. This pattern of results indicates that an invisible vertical orientation contained in the isotropic pattern looking like a bull's eye is sufficient for producing collinear facilitation, and that a degree of facilitation is further enhanced by the perceptual appearance of flankers that is consistent with collinearity. We argue that lateral interactions of orientation-selective units in an early stage of visual processing and feedback from a higher stage of visual processing are both involved in collinear facilitation.

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16.555 **Dichoptic Collinear Lateral Masking at Long Stimulus Onset Asynchronies Produces Surprising Suppression of Contrast Detection**

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At VSS 2010 we reported the results of a pilot study that investigated the effect of varying interstimulus interval (ISI) and flank duration on contrast detection threshold (CDT) of a sinusoid target under monoptic and dichoptic viewing. We now report on the completed study including half-binocular viewing, longer stimulus onset asynchronies (SOA), and a supplemental experiment using orthogonal flanks. 11 observers with normal vision participated for a mean of 25 hours each. In the main experiment, target and flanks were 3 cpd vertical sinusoids with 6 lambda (sigma = 1.5 lambda) center-to-center vertical separation. Flank contrast was normalized to 3X flank CDT. Flanks were presented at 4 durations (67-500ms) and ISIs at 7 durations (0-2500ms) resulting in SOAs from 0-3000ms. Target presentations were 250ms to the dominant eye via mirror haploscope and septum. Flanks were presented to dominant (monoptic and half-binocular) and non-dominant eyes (dichoptic and half-binocular). Forward masking was used with a 1-FC detection paradigm and 7-level MOCS. Each threshold was calculated from approximately 700 trials. As expected, simultaneous presentation resulted in CDT facilitation (monoptic = 18.9±3.86% (SE), dichoptic = 13.9±4.00%, half-binocular = 18.0±4.20%). For all viewing conditions, relative facilitation decreased as SOA increased up to 1000ms. Surprisingly, dichoptic and half-binocular viewing showed CDT suppression at long SOAs beginning at 400-500ms, with maximal suppression (9.9±5.1% and 5.3±4.7%, respectively) occurring at 1000ms. All viewing conditions approached no effect at the longest SOAs (1500-3000ms). Flank duration had a significantly greater contribution to the overall effect than ISI for dichoptic and half-binocular viewing. We found no significant difference in contribution under dichoptic viewing. Dichoptic, orthogonal flanks did not produce CDT suppression. We speculate that the CDT suppression observed at long SOAs under dichoptic and half-binocular viewing is due to one-way, contrast adaptation from lateral propagation that produced the effect of a collinear, illusory contour.

16.556 **Components of the curveball illusion: changes in perceived motion of the envelope across the visual field.**

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The curveball illusion (Shapiro et al., 2010) demonstrates a failure of the peripheral visual field to integrate motions without loss of location information. Our objective is to examine how the two motion components independently influence the illusion strength across the visual field. Previously we have shown that the loss of location information occurs across the whole visual field, except in the very center (VSS 2011). Further, we have shown that the illusion strength depends on the judged velocity of the grating component, and not the real velocity. Here, we wanted to explore how the perceived motion of the envelope component varied across the visual field, and how the local carrier interacted with this perceived motion. Here we used a Gabor version of the illusion, with left/right local carrier motion, and up/down Global envelope motion. In each case, the velocity of the carrier or envelope motion was varied. Illusion strength was measured in terms of perceived trajectory angle with respect to vertical. Illusion strength was measured from fixation (0 deg) to 15 deg eccentricities for both speed variations. We found that the perceived speed of the Gabor envelope in the periphery was slower than that of the same speed when perceived at the point of fixation. Also, at each eccentricity there is a point-of-perceived equality where both the carrier and envelope motion appear to be moving with the same velocity. Taken together with our previous findings, we find that the curveball illusion is well described in terms of the perceived component motion speeds (not the real velocities). This, a vector model calculated using both component motion speeds can describe the strength of the illusion. We consequently find that the relationship of the increase in illusion strength with increasing eccentricity can be described using this vector model.

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16.557 **Contrast-negation and texture synthesis differentially disrupt natural texture appearance**

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Contrast-negation and texture synthesis each disrupt the appearance of natural textures. Both manipulations preserve some features (e.g. isophotes in contrast-negation, summary-statistics comprising the synthesis model)

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while disrupting others (e.g., local phase in contrast-negation, higher-order statistics in texture synthesis). Here, we examined the extent to which contrast-negation and texture synthesis each introduce or remove critical perceptual features for discrimination from natural textures using a 4AFC oddball detection task. Individual trials were comprised of 4 unique circular texture patches (~1 degree): 3 distracters drawn from one texture and a single target drawn from a different source. Participants had unlimited time to freely view the images and identify the target. In Experiment 1, participants (N=13) were to discriminate between synthetic and natural images of the same texture, with varying positive/negative contrast of all test stimuli, and varying oddball type (real/synthetic). In Experiment 2, participants (N=11) discriminated original from contrast-negated images of the same texture. We varied whether all test textures were natural or synthetic and also varied oddball type (positive/negative). In both experiments, we used images of food and abstract artwork in separate blocks. In Experiment 1, synthetic oddballs were easier to identify than real ones in abstract art blocks, but harder to identify in food images (category x oddball interaction, p = 0.03). This interaction suggests that synthesized patches of natural textures have less appearance variation than patches of the original texture, but that the converse is true for synthetic images of abstract artwork (which minimizes the role of synthesis artifacts in driving the effect). In Experiment 2, we observed no main effects or interactions of oddball type, suggesting that contrast-negation does not affect the perceived variation in appearance to the same extent that texture synthesis does, even though this manipulation also compromises many of the same appearance properties of natural textures.

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16.558 **Contour interaction extents (in MAR) for differently-sized Cs vary little within,** but lots between, LM and CM acuity systems.

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Visual acuity for contrast-modulated (CM) Cs is ~0.3logMAR higher than for luminance-modulated (LM) Cs, consistent with larger summation areas for CM stimuli (Hairol et al, VSS2010; Sukumar & Waugh, 2007). The extent of contour interaction for LM and CM Cs is similar when scaled for letter size, which implies a fixed extent for each letter processing system. However, acuity studies themselves employ a range of letter sizes. In this study we assessed whether fixed letter sizes and spatial extents scale in MAR, within and between, LM and CM spatial acuity systems. First, we revisited contour interaction on visual acuity data (Formankiewicz et al, VSS2010). Psychometric functions generated were compared for same size Cs, and extents estimated across ~2.5x range of sizes for LM and CM systems. Performance functions for contour interaction were also measured using fixed sized Cs on new observers. The 80% performance level was selected for unflanked Cs and then bars were placed 1-200 arcmin from the C. C modulation depth was varied and data for a 5-6.5x range of C sizes for both the LM and CM systems (LM: logMAR 0.1 to 0.9 and CM: logMAR 0.6 to 1.3) was gathered. Foveal visual acuity data revealed that within a system, larger letters do not consistently produce larger contour interaction extents (in MAR). When different letter sizes are required by the LM and CM systems, spatial extents are different. Performance function data confirm that extents vary little within each system (LM 1-3 arcmin; CM 6-12 arcmin). Foveal C acuity displays contour interaction extents that do not systematically vary, despite differences in letter size. Across LM and CM systems, acuities and extents are different. The results have implications for visual acuity processing of LM and CM stimuli and on masking models of foveal contour interaction.

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16.559 **Integration of texture and color cues for visual shape recognition**

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The visual system can use multiple cues, including brightness, texture, color, and motion, to segment figure from background. We studied how two cues, texture and color, combine for visual shape recognition. Two experiments tested whether texture and color are processed independently for the identification of letters. Methods. Observers identified 10x10 deg letters (Sloan font, 5 possible: DNRSZ) that were briefly displayed (250 ms) in the center of the screen. Letters were composed of oriented, filtered noise (1 cycle/deg peak SF, bandwidth 1 octave; orientation bandwidth 30 deg) in both foreground and background. We used "second-order" letters: The letter differed from background in dominant orientation (texture cue) and/or the hue-luminance association (color cue; dark-red/bright-green foreground and bright-red/dark-green background, or vice versa). The letter and background had identical mean luminance, hue (gray), and luminance contrast. Performance was determined as a function of second-order modulation contrast. Results. Experiment 1: Letter-identification thresholds were determined for the texture cue alone, for the color cue alone, and for three two-cue conditions differing in relative chromatic and texture contrast. Compared to single-cue conditions, two-cue thresholds showed improvement consistent with pooling of independent cues. Experiment 2: Observers identified the letter defined by one cue (e.g., texture) while ignoring the other cue (e.g., color). The "ignored" cue signaled either the same letter (congruent trials), a different letter (incongruent trials), or no letter at all (baseline), randomly across trials. Compared to baseline, performance was better on congruent trials and worse on incongruent trials. Analysis of errors on incongruent trials revealed that observers often responded according to the irrelevant cue. Conclusion. Human observers can integrate texture and color cues for improved shape recognition. While this improvement is consistent with independent processing of texture and color, observers cannot discount irrelevant color information when identifying shape based on texture, and vice versa.

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16.560 **The nonlinearity in texture segregation is not rectification**

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The filter-rectify-filter (FRF) model has been adopted as a standard explanation of texture segregation. FRF consists of a first stage linear filter (to enhance a constituent texture), nonlinear rectification (computation of "texture energy"), followed by linear filtering tuned to the texture-defined signal. We estimated the spatial-frequency bandwidth of the second filter using two techniques: critical-band masking and 2X2 detection/identification (Watson & Robson, Vis. Res., 1981). The former indicated no 2nd-order tuning, while the latter (along with previous summation results) did find tuning. Including a local winner-takes-most nonlinearity on texture energy can reconcile these seemingly contradictory findings. Methods. Critical-band masking: 2AFC 2nd-order orientation discrimination. Carrier patterns were 45 and 135 deg gratings. Modulators were vertical or horizontal gratings plus low- or high-pass masking vertical/horizontal plaid noise. Noise cutoff frequency was varied across blocks and 2nd-order threshold modulation contrast was determined by staircase. The derivative of threshold elevation as a function of cutoff yields an estimate of the spatial-frequency channel. 2X2 task: There were two intervals per trial. One contained zero modulation and the other contained a modulator with one of two possible frequencies. Observers indicated both the interval containing the modulator (detection) and its frequency (discrimination). We report channel bandwidth estimates based on maximum-likelihood fits of a 2-channel model to the data. Results. Critical-band masking indicated no 2nd-order frequency tuning; noise elevated threshold independent of noise frequency relative to signal frequency. The 2X2 experiment yielded bandwidth estimates of 1-1.5 octaves consistent with previous summation experiments. We compare these results to simulated variants of the FRF model. The critical-band masking results differ dramatically from predictions of the standard FRF model. However, untuned response to noise can be explained by an additional nonlinear processing step that computes a local soft-max on texture energy before second-stage filtering (with filter-bandwidth taken from the 2X2 experiment).

Acknowledgement: NIH EY16165

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Saturday Morning Talks

Color and light: Mechanisms

Saturday, May 12, 8:00 - 10:00 am

Talk Session, Royal Palm Ballroom 1-3

Moderator: Kathy Mullen

21.11, *8:00 am*

Somali color vision and color naming

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How are words used to communicate about color? Berlin & Kay (1969) conjectured that world languages have 2-11 Basic Color Terms (BCTs), which are used with high consensus and consistency within each language to name colors falling within distinct color-categories. Contrary to that conjecture, our post-hoc statistical analysis of the World Color Survey (WCS) data set (PNAS, 2009) indicated striking within-language diversity in color term usage, with about 3-4 distinct color-naming systems ("motifs") represented in most languages. Here, we tested this result prospectively by examining Somali, a Cushitic language that was absent from the WCS. Traditional lexicographic analysis (Maffi, 1990) classified Somali as a 6-BCT language: black (madow), white (cadaan), red (garuud, casaan) yellow (cawl, haruud), green (cagaar), and blue (buluug). We tested 32 monolingual Somali subjects (age: 26-92) through an interpreter, using 83- or 145-sample subsets of the WCS color chart. We assessed color discrimination with AO-HRR pseudoisochromatic, and D-15 and FM-100 arrangement tests. Subjects used 60 total color terms, average 13.5 terms/subject. As predicted from our previous work, the Somali data set included examples of each of the 4 motifs discovered by our WCS analysis. Usage of color terms previously classified as "basic" was remarkably diverse: e.g., cagaar meant green, light green, or green-or-blue; buluug meant blue, green, purple, or gray. Somali D-15 scores were many times the standard age-norms (Bowman, 1984), and their FM-100 scores were equivalent to those of English speakers about twice their ages (Knoblauch et al., 1987). Despite difficulty with these arrangement tests, 31/32 Somali subjects gave normal results on the AO-HRR plate test. The striking within-language diversity in Somali color term usage, and Somalis' selective difficulty with arrangement tests of color vision, challenge traditional views concerning the nature of color cognition and communication within a culture.

Acknowledgement: NIH/NEI R21-EY018321-0251, Ohio Lions Eye Research Institute

21.12, *8:15 am*

Colour boosts performance in visual search for natural objects

Anya Hurlbert[1](anya.hurlbert@ncl.ac.uk), Paik Hwa Chow[1], Angela Owen[1]; [1]Institute of Neuroscience, Newcastle University

Colour and shape are powerful cues to object identity, but do not contribute equally for all objects and all recognition tasks. Colour is more effective than shape in driving rapid classification of natural objects when both cues are diagnostic (Ling et al, VSS 2009). Here we investigate the advantage of colour cues in a visual search task. Target objects (fruits) were arranged in typical configurations (fruit bowls) with distractors drawn from a wider range of fruits. For each object, a set of calibrated images was created for each of four conditions: target normal colour, target abnormal colour, target grayscale, and all fruits grayscale. In each set, the target-present image was paired with 9 distinct target-absent images, in which the spatial configuration was varied while maintaining similar sizes, shapes and colours of the distractors. Each trial began with the target object's name displayed in text (1000 ms), followed by a central fixation cross (250 ms), followed by a 9-image RSVP sequence (either target-present or -absent) lasting 100 ms. Subjects (n=12) responded as rapidly as possible. Across all objects, sensitivity in detecting the target was highest for targets presented in natural colour, and lowest for targets presented in grayscale. RTs varied significantly across objects. We conclude that colour cues are more effective than luminance cues in this visual search task. Even for objects with distinctive shapes such as the banana, which is detected significantly faster and with greater accuracy than other objects, sensitivity in the natural colour condition is greater than in all other conditions. The fact that abnormal-colour targets are detected more rapidly than normal-colour targets for objects with low diagnostic shape implies that colour plays two distinct roles in object detection: colour enhances the recognition of target objects and also their segmentation from the background.

Acknowledgement: Newcastle University

21.13, *8:30 am*

Simultaneous contrast and gamut relativity in brightness and darkness perception

Tony Vladusich[1]; [1]Biology Department, Brandeis University

Simultaneous contrast refers to the respective brightening (darkening) of physically identical image regions surrounded by neighboring regions of low (high) luminance. A common method of measuring the strength of simultaneous contrast is color matching, in which subjects adjust the luminance of a target region to achieve an achromatic color match with another region. A recent model of model of achromatic color perception suggests that such color matches are relative, rather than absolute, reflecting minimal perceptual distances between colors represented as points in a two-dimensional (2D) color space composed of brightness and darkness dimensions (brightness-darkness space). Here we present psychophysical data supporting this model, and show that achromatic colors are computed as the vector sum of weighted luminance and contrast information in brightness-darkness space. According to the model, simultaneous contrast restricts the color gamut available to subjects performing a color matching task to different 1D slices of brightness-darkness space, with each slice depending uniquely on the luminance values in surrounding image regions. We term this concept gamut relativity.

21.14, *8:45 am*

Two routes to suppression of signals in color vision

Kathy T. Mullen[1](kathy.mullen@mcgill.ca), Mina Gheiratmand[1], José M. Medina[1], Yeon Jin Kim[1]; [1]McGill Vision Research, Dept of Ophthalmology, McGill University

There are at least two routes to psychophysical cross-orientation suppression prior to binocular summation of the signal in achromatic vision: (1) a monoptic, non-adaptable sub-cortical pathway and (2) a dichoptic, adaptable interocular pathway (Baker et al., Neuroscience, 146, 2007). Here we test psychophysically whether cross orientation masking (XOM) in color vision (Medina & Mullen, JOV 9(3), 2009) has gain-control pathways that are separable from achromatic responses or whether chromatic and achromatic responses interact. Methods: Detection threshold vs contrast (TvC) masking functions were measured for red-green isoluminant, horizontal Gabor targets overlaid with achromatic vertical Gabor masks. We tested for XOM under a range of spatiotemporal conditions (0.375, 0.75 & 1.5 cpd; 2 & 8 Hz), and with the chromatic test and achromatic mask presented under monoptic, dichoptic, and binocular viewing conditions. Results: We find that: (1) there is little or no cross orientation masking of color by achromatic contrast under monoptic or binocular conditions at any of the spatio-temporal frequencies tested, although some facilitation may occur; (2) there is significant dichoptic XOM, when mask and test are present to different eyes, which increases with mask contrast; (3) the dichoptic XOM is greater at low temporal frequencies (2 Hz) than high (8Hz). Conclusion: The significant inter-ocular cross orientation suppression of color by luminance contrast indicates that gain control pools at this level are unselective for chromaticity. Our results support a two-stage contrast normalization model with both a monocular and a dichoptic stage prior to binocular summation: the within eye, monocular stage of suppression is selective for color contrast whereas the inter-ocular second stage, revealed under dichoptic conditions, has color-achromatic interactions. This differential effect provides evidence for at least two distinct sites for suppressive gain control in color vision.

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21.15, *9:00 am*

Color confusion ellipses from absolute judgments

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The axis of maximum variability in settings of unique white lies near the blue/yellow diagonal in the MacLeod-Boynton chromaticity diagram (Beer and MacLeod, VSS 2005). This axis coincides with the locus of natural day-

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light illuminants. A possible reason for this oblique orientation is color constancy. An observer may be willing to accept as white any chromaticity that could plausibly be interpreted as a white reflectance spectrum under a natural illuminant, and natural illuminants vary mainly along this blue/yellow direction. Here we extend this work to points in chromaticity space other than unique white. Observers were asked to memorize the color of a particular stimulus, presented in a dark surround, at the beginning of an experimental session. Observers fixated a single-pixel central fixation dot, and the stimulus was presented parafoveally, rotating through twelve positions around the fixation dot in order to avoid adaptation of one particular retinal location. Observers were then required to set matches to this remembered chromaticity for the rest of the session. The matching stimulus also rotated around a centrally presented fixation dot, and observers adjusted its chromaticity within an isoluminant plane using a tracker ball. Each observer set 35 matches to each remembered color. The distributions of matches show a blue/yellow diagonal elongation. This elongation is not attributable to nonuniformity of the chromaticity diagram, since it is more pronounced in absolute color judgments than in side-by-side-discrimination. A possible explanation for our results is color constancy: observers remember an "object" with a particular reflectance spectrum, and accept as color matches to this object the chromaticities which that reflectance spectrum yields under a range of plausible natural illuminants.

21.16, *9:15 am*

S-cone pathways

Caterina Ripamonti[1](c.ripamonti@ucl.ac.uk), Gordon Henning[1], Andrew Stockman[1]; [1]UCL, Institute of Ophthalmology

In the presence of a background that excites M- and L-cones, there is clear evidence for an unusual S-cone luminance contribution that is delayed and inverted with respect to the usual M- and L-cone signals (Stockman et al., 1991; Ripamonti et al. 2009). This S-cone contribution, however, disappears in the absence of any background, which suggests that it may be some form of gain control acting on existing L- and M-cone signals (rather than being a direct contribution). Here, we continue our investigation of S-cone pathways by looking at S-cone signals in observers with unusual syndromes: some with only S-cones (S-cone monochromatism or Blue-cone monochromatism BCM), and others with an excess of S-cones in whom S-cones have replaced rods during development (enhanced S-cone syndrome or ESCS). We measured their temporal modulation transfer functions at three time-averaged 440-nm target radiances of 7.40, 8.73 and 9.61 log10 quanta s-1 deg-2. Each flickering 4°-diameter target was superimposed in the centre of a steady 9°, 620-nm background of 11.41 log10 quanta s-1 deg-2 to isolate the S-cone response. At all target levels, we found evidence for increased S-cone temporal sensitivity in the BCM and ESCS observers, but with unexpected and abrupt sensitivity peaks. These peaks are consistent with constructive and destructive interference between fast non-inverted, and slow inverted signals, suggesting the existence of multiple S-cone signals. We suspect that the slow, inverted signal is comparable to the sluggish gain control found in normals, but in these syndromes acting on an existing S-cone signal. In the ESCS observers, we were able to measure the S-cone luminance contribution (relative to M- and L-cone signals). Remarkably, the S-cone contribution is also slow and inverted as it was in normals. Apparently, even in ESCS observers, any S-cone luminance contribution is still indirect.

Acknowledgement: BBSRC

21.17, *9:30 am*

An Unsupervised Learning Technique for Typing Cones in the Retinal Mosaic

Noah Benson[1,2](nbe@sas.upenn.edu), David Brainard[1]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

Extracting color information from the interleaved retinal cone mosaic requires taking account of the spectral type (L, M or S) of each cone. Yet, there is no known biochemical mechanism that distinguishes L and M cones. We therefore ask whether unsupervised learning can distinguish the types of retinal cones. To investigate, we computed the responses of simulated cone mosaics to calibrated natural images. We considered mosaics with L:M cone ratio varying from 7:1 to 1:7, with the number of S cones held at ~7% of the total, and with random assignment of the locations of L and M cones. To learn cone types, our algorithm first found the correlation matrix of the responses of all of the cones in the mosaic. It then treated the correlation between any pair of cones as a measure of that pair's similarity and applied non-metric multidimensional scaling to embed each cone at a location in a three-dimensional space, such that the distance between any pair of cones was monotonically related to that pair's similarities. Density clustering was applied to the three-dimensional representation to find the best three-cluster representation. These clusters correctly grouped together cones of each type for all of our simulated mosaics, based on responses to ~5000 natural images: cone types can be learned without the need for biochemical identification. The feature of natural images and cone spectral sensitivities that supports unsupervised learning via our algorithm is that highly correlated cone pairs are highly likely to be of the same type, as long as the maximum retinal distance between cones of the same type is not too large. Further calculations should allow us to elucidate boundary conditions (e.g., separation of L and M lambda-max, L:M cone ratio) on when unsupervised learning is possible, and thus inform theories of how color vision evolved.

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21.18, *9:45 am*

Contrast adaptation can make test items invisible

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Adaptation to time-varying contrast reduces the visibility of subsequently viewed grey test items (Webster & Mollon, JOSA A 1993, 10, 1332-40). We adapted to a contour-rich "#" pattern and tested on congruent patterns of different contrasts, using a constant-stimuli matching method. Results were linear: All test contrasts were uniformly reduced subjectively to 60% of their physical value. Adapting to a non-congruent, slightly larger square patch covering the same area had less effect, showing the importance of contours. Adaptation to a high-contrast photograph that alternated (flickered) between positive and negative reduced the visibility of low-contrast test photos of the same person, whether these were positive or negative.

Visual awareness

Saturday, May 12, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 4-5

Moderator: Jonathan Peirce

21.21, *8:00 am*

Is it just motion that silences awareness of visual change?

Jonathan Peirce[1](jon@peirce.org.uk); [1]Nottingham Visual Neuroscience, School of Psychology, University of Nottingham

Suchow and Alvarez (2011) present a compelling illusion in which subjects fail to notice changes in a rotating array of elements that are quite obvious in a similar static array. Awareness of changes to the element size, colour, luminance and shape can all be 'silenced' in this manner. This appears to indicate that the perception of motion is of particular importance to the visual system, such that the presence of a moving stimulus completely dominates our visual attention. We wondered whether the converse effects are possible; whether salient, coherent changes in some other dimension, such as colour or size, are able to silence our awareness of motion. We also wanted to generate a 2AFC task, in which subjects made judgements about the rate of change, rather than having subjects make a judgement about how strong they felt the effect was. This enables us to test naïve observers, since we don't need to explain the effect to them. Subjects were presented with two circular annuli of dots that were changing in some dimension (size, colour or position). One of the stimuli was also exhibiting some additional 'distracting' change in one of the three dimensions (but not the task dimension). Subjects reported which of the two stimuli was changing most rapidly in the task dimension. Using a 2AFC task and a staircase procedure the point of subjective equality (PSE) was determined. The PSE was very substantially shifted in all cases to indicate a silenced awareness of the change in the distracting stimulus, regardless of whether that distraction was a coherent motion, coherent size change or coherent colour change. Motion, it seems, is not special in its ability to silence awareness; coherent changes in colour or size can also silence our awareness of incoherent dot motion.

21.22, *8:15 am*

Graded vs. Quantal Allocation of Attention and Awareness

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Graduate Medical School, Singapore, [3]Department of Psychology, Harvard University. Cambridge, MA

The Attentional Blink (AB) refers to the profound impairment in consciously detecting the second of two targets presented serially among distractors, when that second target (T2) occurs within 500ms of the first (T1). The AB paradigm has recently been used to investigate whether conscious perception is a graded or quantal (all-or-none) state, with conflicting results (Sergent & Dehaene, 2004; Nieuwenhuis & de Kleijn, 2011). This discrepancy may stem from the use of indirect methods that probed the participants' subjective reports of conscious states rather than probing the quality of the conscious content per se. To address this issue, here we used a mixture modeling approach (Zhang & Luck, 2008) that independently estimates the probability of consciously perceiving a target and the precision at which that target is perceived. By measuring representational quality across temporal intervals in the AB we can directly infer whether limitations of temporal attention lead to graded (as expressed by changes in perceived target precision) or all-or-none (as expressed by changes in probability of target perception) changes in conscious percepts. We found that the probability of consciously perceiving T2 was strongly affected by the SOA between T1 and T2 but the precision at which that target was perceived remained unaffected. This was the case for both simple (colors) and complex (faces) stimuli, and across AB paradigms (RSVP and skeletal ABs). In a final experiment we varied the amount of attention available for T2 processing by manipulating the extent to which T1 captured attention. With increased attention to T1, there was a reciprocal decrease in the probability of consciously perceiving T2, but no effect on its precision. These results suggest that conscious perception is all-or-none in the AB, and that attention acts as a capacity-limited resource that modulates the probability of occurrence of this quantal percept.

21.23, *8:30 am*

Semantic Wavelet-Induced Frequency Tagging (SWIFT) tracks perceptual awareness alternations in an all-or-none fashion.

Roger Koenig-Robert[1](roger.koenig@cerco.ups-tlse.fr), Rufin VanRullen[1]; [1]CerCo - CNRS - Université Paul Sabatier

Defining the neural correlates of awareness has been difficult due to the lack of selective means to measure consciousness-dependent activity. A widely used paradigm to explore visual awareness is binocular rivalry (BR): conflicting monocular images alternate every few seconds, with the dominant stimulus transiently gaining access to consciousness, while the non-dominant becomes invisible. From single-unit recordings in primates to whole brain EEG or fMRI recordings in humans, current techniques have only found moderate modulations of neural activity when stimuli are dominant versus when they are not; all techniques systematically reveal a significant response to invisible stimuli. SWIFT (semantic wavelet-induced frequency-tagging) is a recently developed EEG technique which selectively tracks high-level representations with high temporal resolution (Koenig-Robert & VanRullen, VSS 2011). SWIFT uses cyclic wavelet-scrambling to modulate the semantic content of an image at a temporal frequency f0, while conserving low-level features. We used SWIFT to measure perceptual alternations during BR. Two face pictures, one red and one green, were modulated under SWIFT at different f0 (1.4894 and 2 Hz) and presented monocularly. Two kinds of alternations were used: BR, where the two stimuli were presented simultaneously (and only one was perceived at a time), and physical alternation (PA), where the stimuli were presented alternately in each eye, mirroring the dynamics of BR spontaneous alternations. Subjects (n=9) reported the color of the perceived face. Fronto-central and occipito-temporal EEG activities were elicited by dominant stimuli, and were comparable in their topography and amplitude in PA and BR conditions. Crucially, non-dominant stimuli in BR elicited no more activity than the response to a blank screen in PA. SWIFT thus makes it possible to non-invasively record brain signals that are not merely modulated by BR, but follow its perceptual alternations in an all-or-none fashion, exactly as their phenomenal counterpart does.

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21.24, *8:45 am*

Are the neural correlates of conscious contents stable or plastic?

Kristian Sandberg[1,2](krissand@rm.dk), Morten Overgaard[1,3], Geraint Rees[2,4]; [1]Cognitive Neuroscience Research Unit, Aarhus University Hospital, [2]Institute of Cognitive Neuroscience, University College London, [3]Cognitive Neuroscience Research Unit, Dept. of Communication and Psychology, Aalborg University, [4]Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London

It is often an implicit assumption of consciousness research that the neural correlate of a particular conscious experience is both universal (shared between subjects) and stable over time. Recently, we demonstrated that the first assumption is only partially true, and in the present study we examine the second assumption. We recorded the magnetoencephalographic (MEG) signal from healthy human participants while they viewed an intermittently presented binocular rivalry stimulus consisting of a face and a grating. During binocular rivalry, the stimulus is kept constant, but the conscious content alternates between two possibilities. Using a multivariate classification algorithm, we found that it was possible to predict the conscious experience of a participant from early event-related field components (100-300ms after stimulus presentation) using data gathered on different trials of the same recording session. Very similar accuracies were obtained when the data used to train and test the classifier were gathered on different days within a week. However, when training/testing data were separated by 2.5 years, prediction accuracy was reduced drastically, to a level comparable to when the classifier was trained on a different participant. We discuss whether this drop in accuracy can best be explained by changes in the predictive signal in terms of timing, topography or underlying sources. Our results thus show that the neural correlates of conscious perception of a particular stimulus are stable within a time frame of days, but not across years. This may be taken as an indication that our experience of the same visual stimulus changes slowly across long periods of time, or alternatively the results may be understood in terms of multiple realizability.

Acknowledgement: The work is supported by the European Research Council and the Wellcome Trust.

21.25, *9:00 am*

Unconscious contingency learning modulates conscious visual perception

Qian Xu[1](xuq@psych.ac.cn), Li Wang[1], Yi Jiang[1]; [1]Key Laboratory of Mental Health, Institute of Psychology, Chinese Academy of Sciences

People can readily detect critical contingencies between different objects or events. Here, we report that contingency learning can occur even when the stimuli are not consciously perceived. In a design that combines a dot probe paradigm and interocular suppression, we rendered two faces (with fearful and neutral expressions) invisible and their locations random, one of which, however, was always followed by a probe. Observers improved over time on the probe discrimination task, implying that they could learn the spatial contingency between the probes and the invisible faces. Crucially, such improvement was not due to practice effect, as it disappeared when the contingency was absent. More intriguingly, following the learning, the face associated with the probe, though not consciously perceived by observers, could nevertheless prolong its dominance in binocular rivalry over the other face. To sum up, contingency learning can occur unconsciously, which further enhances the visual representation of the contingent stimulus at the conscious level.

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21.26, *9:15 am*

Attentional allocation to unconscious faces

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Recent psychophysical experiments have demonstrated that unconsciously presented stimuli of potential behavioral relevance to an observer can influence the allocation of spatial attention (Jiang, Costello, Fang, Huang, & He, 2006; Lin, Murray, & Boynton, 2009) However, evidence for such unconscious attentional modulation in normal observers is limited to a few unusual categories of unconscious stimuli (e.g., nude bodies and looming dot-motion). If modulation of spatial attention by unconscious stimuli is a common phenomenon in ecological vision, one would expect that more frequently encountered stimuli would also have effects on attention. We hypothesized that unconscious emotional faces would influence attentional

Saturday AM

allocation because of their behavioral relevance. We presented dynamic fearful and angry face stimuli unconsciously using continuous flash suppression (Tsuchiya & Koch, 2005; Fang & He, 2005). We find that such unconscious faces can affect observers' performance on a subsequent grating-orientation discrimination task in a spatially-constrained manner. We thus demonstrate for the first time that emotional faces presented unconsciously can affect the allocation of spatial attention in normal subjects. This result suggests that modulation of attention by unconscious stimuli could be an everyday occurrence.

Acknowledgement: This research was supported by an NSF GRFP award to E.A.R.

21.27, *9:30 am*

Revealing the face behind the mask: Emergent unconscious perception in object substitution masking

Stephanie Goodhew[1](s.c.goodhew@gmail.com), Susanne Ferber[1], Sam Qian[1], David Chan[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

Human visual awareness is inherently limited. We are conscious of only a small fraction of the available information at a given point in time. Given this limitation, vision scientists have long been fascinated with the depth of processing that occurs outside of awareness, and have thus developed a number of tools for rendering stimuli unconscious, including object substitution masking (OSM). In OSM, perception of a briefly-presented target image is impaired by a sparse common-onsetting, temporally-trailing mask. To what level are successfully masked targets processed? Existing evidence suggests that OSM disrupts face perception. That is, the N170, an ERP waveform that reflects face processing, was obliterated by the delayed offset of the mask (Reiss & Hoffman, 2007). Here, however, we found the first evidence for implicit face processing in OSM. Participants were presented with an OSM array that had either a face or a house target image, followed by a target string of letters that required a speeded lexical decision. Participants then identified the target image from the OSM array. On trials in which the target image was masked and not perceived, we found priming, such that responses to the target word were facilitated when the meaning of the word was compatible with the preceding image, compared with when it was incompatible. That is, the category to which the target object belonged (face, house) systematically influenced participants' performance of another task. This reveals that there is indeed implicit face perception in OSM. Interestingly, this priming occurred only when participants were unaware of the target. The fact that priming was specific to trials where the target was not perceived demonstrates a qualitative distinction between conscious and unconscious perception. This implies that unconscious perception is more sophisticated than a merely impoverished version of conscious recognition.

Acknowledgement: Ontario Ministry of Research and Innovation PDF NSERC CIHR

Scene perception: Mechanisms

Saturday, May 12, 10:45 - 12:30 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Serge Dumoulin

22.11, *10:45 am*

Post-detection at 13 ms/picture in RSVP

Mary C Potter[1](mpotter@mit.edu), Brad Wyble[2], Emily McCourt[1]; [1]Massachusetts Institute of Technology, [2]Syracuse University

Last year we reported preliminary results (since replicated) showing above-chance detection of a picture in a rapid serial visual presentation (RSVP) on the basis of a verbal title given just before the sequence (e.g., cut up fruit), at a duration as short as 13 ms/picture. Here we report that viewers can recognize that they have just seen such a target, when the verbal title is given directly after the sequence (post-detection). We presented color photographs of a wide variety of scenes at rates of 80, 53, 27, and 13 ms/picture in six-picture RSVP sequences; the sixth picture functioned as a mask and was never the target. All pictures were new to the participants and none were repeated in the experiment. Performance with the post-cue was significantly above chance at all durations. Whether or not the participant reported detection of the target, each target trial was followed by a forced choice test between two pictures, both of which matched the target title (but only one had been in the sequence). With this more severe test, performance was significantly above chance at all presentation durations except 13 ms. Other studies indicate that memory for such rapidly presented pictures declines quickly if the target name is delayed. This work suggests that specific object and gist identities can be activated transiently even at extremely high rates of presentation, presumably by feed-forward processing, even when the participant does not know which picture is the target until after the sequence. That is, advance tuning is not necessary for perception, even at these high rates.

Acknowledgement: MH 47432

22.12, *11:00 am*

The Gist of the Abnormal: Above chance medical decision making in the blink of an eye.

Karla Evans[1,2](kevans@search.bwh.harvard.edu), Jeremy Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

Global structural and statistical regularities allow the gist of a real world image to be extracted after as little as 20 msec exposure. Would this work with artificial stimuli such as mammograms and/or Pap tests for cervical cancer? Experts certainly think that they can sense the presence of abnormalities before they can find them. We tested this ability in two expert populations, radiologists and cytologists. Forty-three expert radiologists were presented with 100 trials of craniocaudal or mediolateral oblique x-ray views of both breasts. Thirty-eight cytologists saw 120 Pap test images (micrographs of many cervical cells). Exposures were 250-2000 milliseconds. Each observer saw a mix of images at two different durations. Observers rated the abnormality of an image on a 0-100 analog scale. Observers also attempted to localize abnormalities on a subsequent screen showing only the outline of the image. Half of the cases were verified as not having any abnormality. The other half had various subtle abnormalities. Presence of abnormality and duration were randomized across trials. Both groups of experts had above chance performance for detecting subtle abnormalities at all stimulus durations (cytologists D' ~1.2 and radiologists D' ~1). Control groups did not differ from chance. The ability to localize the abnormalities was poor, with 12% correct localization of abnormal regions for radiologists and 16% for cytologists. Of course, no one would suggest performing cancer screening in 250 msec. D' for expert radiologists is 2.5-3.0. However, these findings suggest that there is a global signal that allows experts to detect the gist of abnormality very rapidly. The failure to localize these abnormalities suggests that this is a global signal and not fortuitous attention to a localized target. It is possible that this global signal could be exploited to improve clinical performance.

Acknowledgement: NRSA F32EY019819-01 grant to KKE and NEI EY17001 and ONR MURI N000141010278 to JMW

22.13, *11:15 am*

Semantic and Syntactic Inconsistencies in Scenes Elicit Differential ERP Signatures.

Melissa Vo[1](mlvo@search.bwh.harvard.edu), Jeremy Wolfe[1]; [1]Harvard Medical School, BWH

We have evolved to be efficient searchers by making use of the regularities of our visual world. We rapidly register two types of regularity violation: Incongruous objects in scenes are "semantic inconsistencies" (a fire-hydrant in the kitchen). Misplaced objects are "syntactic inconsistencies" (a fork on the kitchen chair). ERPs differentially reflect semantic and syntactic errors in language. Does the brain honor such differences in vision? Previous studies (Ganis & Kutas, 2004; Mudrik, Lamy, & Deouell, 2010) have shown an "N390/N400 scene congruity effect" for semantic inconsistencies, similar to the semantic N400 effect found in sentence processing. We compared ERPs for semantic and syntactic anomalies in scenes. We collected EEG data from 64 electrodes while participants attempted to memorize scenes containing an object that was either syntactically inconsistent, semantically inconsistent, both, or neither. First, the scene without the critical object was presented (500ms), followed by a location cue that indicated where to move the eyes (500ms). Then the critical object appeared at the cued location (2000ms). We found an N400 for semantic inconsistencies between 300 and 500 ms after object onset. Interestingly, we observed a prolonged deflection of the opposite (positive) sign for syntactic inconsistencies, which might resemble the P600 found for syntax manipulations in sentence processing. When we repeated the same experiment, but presented words in the scene, naming the objects, instead of the objects themselves, we found evidence for an N400 in response to semantically incongruous words in scenes, but no modulation attributable to the syntactically incongruous positioning of words. Together, these findings demonstrate that, as in sentence process-

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ing, semantic and syntactic inconsistencies of objects in scenes elicit differential brain responses. This implies that the semantic/syntax distinction is meaningful in the visual system as it is in sentence processing.

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22.14, *11:30 am*

Neural Coding of Border-Ownership in Natural Scenes

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Discerning occluding objects from their backgrounds is an automatic and fundamental process of vision, called figure-ground perception. The compulsory nature of this process and its profound impact on perception can be observed in many simple 2D displays, such as Rubin's vase/faces illusion. Subsets of neurons in V1, V2, and V4 of the rhesus macaque have a neuronal correlate of this phenomenon. When stimulated with the contour of a figure, these neurons show an elevated firing rate when the figure is on one side of their receptive field (the "preferred" side) versus the other side. Thus, a local piece of a figure's border has the side of the figure encoded by neurons with opposing side preferences (border-ownership coding). About half of the V2 neurons and a smaller proportion of V1 neurons exhibit border-ownership coding even in absence of depth cues (such as stereo disparity or dynamic occlusion). So far, such selectivity has only been demonstrated with displays of simple geometrical shapes (e.g., squares). Here we studied neurons with images of natural scenes in order to evaluate the role of border-ownership under more normal visual conditions. We record from V1 and V2 neurons of a rhesus macaque using microelectrodes. While the subject maintains fixation, we align occlusion-based contours within natural scenes (and manipulations thereof that we use to control for various factors) to the receptive field of the recorded neuron. We show that natural scenes do indeed elicit a preference for the side-of-object in a subset of V1/V2 neurons and that there is a significant agreement with the side-of-figure preference elicited by single squares. Furthermore, we show that the global context rather than information within the classical receptive field elicits most of this side-of-object related difference.

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22.15, *11:45 am*

Using the population receptive field model to identify images from fMRI signals

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Introduction: A recent focus of fMRI analysis is to predict features of the presented stimulus from measured brain signals. Most of these methods use machine-learning techniques, though some use biological models. Biological approaches explicitly model the underlying neural mechanism (Kay et al, 2008) and are therefore independent of predefined stimulus categories. Using a biological model based on population receptive field (pRF) properties with minimal parameters, we show that it is possible to identify any visual image.   Methods: We measured fMRI responses elicited by different visual stimuli using 7T MRI. The stimuli consisted of conventional bar-shaped mapping stimuli, semi-random synthetic stimuli and natural images. First, we estimated the population receptive field properties of each cortical location (Dumoulin and Wandell, 2008). Next, we identified the presented image based on measured fMRI signals and the pRF model. Both steps used distinct stimuli. Using visual field maps V1 to V3, the pRF model predicted fMRI signal amplitudes for many different images. We correlated the measured fMRI amplitudes with those predicted from the pRF model. The presented image was identified by choosing the pRF model prediction with the highest correlation.   Results: Image identification from a dataset of 1000 images is far above chance for visual field maps V1 to V3, but decreases in performance (V1:~64%, V2:~37%, V3:~32%, chance=0.1%, synthetic images). Both standard mapping stimuli and semi-random synthetic stimuli can be used to estimate the pRF properties. Performance is slightly better when the pRF model is trained on similar synthetic images as compared to standard mapping stimuli (V1: 67% versus 60%, respectively). Identification of natural images is also possible, but less accurate. Discussion: The pRF method is a fast and simple biological model, and even when training it on standard mapping stimuli, it can be used for identification of any visual image, including natural images.

Acknowledgement: Netherlands Organisation for Scientific Research (NWO) Vidi grant 452-08-008

22.16, *12:00 pm*

Multi-voxel pattern similarity predicts subsequent visual memory

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Two techniques for investigating the neural coding of stimulus- specific visual information are fMRI adaptation (fMRIa) and multi-voxel pattern analysis (MVPA). To understand and compare how fMRIa and MVPA representations relate to behavior, we scanned eight participants while they viewed repeated presentations of scenes, and tested their subsequent memory for each scene. We observed robust adaptation within the parahippocampal place area (PPA) and greater pattern similarity across repetitions of the same scene relative to non-identical scenes, consistent with previous studies (Epstein & Morgan, 2011; Morgan et al., 2011). Furthermore, we observed that scenes showing greater pattern similarity were more likely to be remembered (Xue et al., 2010), while adaptation measures were not predictive of memory in this study. Interestingly, the amount of adaptation and the degree of pattern similarity was not significantly correlated for either remembered or forgotten scenes. These results inform hypotheses about the mechanisms for visual representation across repeated viewings and how these representations relate to what we later remember.

Acknowledgement: NSF Graduate Research Fellowship

22.17, *12:15 pm*

rTMS to object selective cortex: Evidence of an inverse relationship between object and scene processing using fMRI

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BACKGROUND: Many influential theories of scene perception are object centered (Biederman, 1981) suggesting that scenes are processed by extension of object processing in a bottom-up fashion. However, an alternative approach to scene processing is that the global gist of a scene can be processed in a top-down manner without the need for first identifying its component objects (Oliva & Torralba, 2001). Transient inactivation of the object selective lateral occipital area (LO) of the brain using repetitive transcranial magnetic stimulation (rTMS) has been shown to interrupt object processing yet facilitate scene processing, suggesting a release of inhibitory connections between object and scene pathways (Mullin & Steeves, 2011). The current project further investigates the nature of this interaction between object and scene selective cortex using interleaved rTMS and functional magnetic resonance imaging (fMRI). METHODS: Subjects participated in two sessions of 1 Hz rTMS to area LO and to the vertex (control site). Following each session, subjects performed a one-back repetition task while viewing scene and object stimuli during fMRI. A region of interest analysis was performed on the independently defined object selective LO and the scene selective parahippocampal gyrus (PPA). Peak BOLD activation and beta weights were compared in the two rTMS conditions as well as a third No-rTMS condition. RESULTS: Subjects showed a significant reduction in peak BOLD activation and beta weights in LO subsequent to rTMS to LO compared to the vertex and No-rTMS conditions. In addition, scene selective PPA activation tended to increase subsequent to rTMS to LO compared to the vertex and No-rTMS conditions. CONCLUSION: The transient deficit in object categorization introduced by rTMS to LO that we have previously described is associated with a significant reduction in BOLD signal and beta weights in area LO but an increase in activation in the PPA.

Acknowledgement: NSERC, The Canada Foundation for Innovation

Attention: Neural mechanisms and models

Saturday, May 12, 10:45 - 12:30 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Sam Ling

22.21, *10:45 am*

Cortical Mechanisms Underlying the Attentional Selection of Objects Embedded In Visual Noise

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The visual system is remarkably good at separating relevant object information from surrounding clutter or visual noise. Although attention is known to enhance sensory signals, the role of attention in extracting relevant information from noise is not well understood. Two prominent mechanisms have been proposed based on behavioral studies: Attention may act to amplify responses to all visual input, or it may act as a noise filter, reducing responses to irrelevant noise. A strict amplification mechanism should produce an attentional benefit only in low-noise situations, as by definition, such a mechanism would enhance both signal and noise. By contrast, a noise filtering mechanism should improve stimulus representations only at high noise levels. Here, we examined how attention modulates the representation of objects embedded in visual noise by using fMRI and multivoxel pattern classification to assess the discriminability of cortical responses to different types of objects. Observers either attended to or ignored images of objects belonging to one of four categories, embedded in various levels of visual noise. Pattern classification was used to measure the amount of object-category information present in individual visual areas. If attention acts to filter out irrelevant noise, then attending to the objects should lead to increased classification performance at high noise levels. Such effects were observed in all visual areas, including the primary visual cortex, suggesting that noise reduction begins to operate at the earliest stages of visual processing. However, if attention also acts as an amplification mechanism, then attending to the objects should increase classification performance at low noise levels as well. Such effects were only observed at higher stages of processing, including the FFA, PPA and lateral occipital complex. Taken together, these results suggest that visual attention improves our ability to discriminate objects by first de-noising visual input, and then amplifying this noise-reduced signal.

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22.22, *11:00 am*

Attention improves communication between V1 and MT

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Attention modulates the activity of sensory neurons in early visual areas such as V1 and MT, and is thought to improve the neural representation of behaviorally relevant stimuli. However, direction-selective neurons in MT depend on input from upstream cells in V1 to gain their complex direction-selective tuning (Born and Bradley, 2005, Ann Rev Neurosci; Rust et al., 2006, Nat Neurosci). Thus, it is important to understand not only how attention modulates neural responses in specific areas, but also to understand whether and how attention impacts information transmission between visual areas. Using fMRI and a forward encoding model (Brouwer and Heeger, 2009, J Neurosci), we observe an increase in the response of direction-selective neural populations whose tuning preference is similar to the attended direction of motion, and a decrease in the response of neural populations with dissimilar tuning, in both V1 and MT. The pattern of modulations is predicted by an established linear/non-linear model that describes how information from V1 is integrated by MT neurons during motion processing (Rust et al., 2006). We used this model as well as the pattern of attention modulation of within-area correlations (Cohen and Maunsell, 2011, Neuron) to predict how cross-area correlations between V1 and MT would change as a function of attention. In consonance with the model's prediction, we find that that correlations between like-tuned populations of direction-selective neurons decrease, whereas correlations between unlike-tuned populations increase. Finally, we use a multivariate Mutual Information metric to show that the observed changes in gain and cross-area correlations have a constructive functional role; they lead to an increase in the synergistic information coupling between direction-selective populations of V1 and MT.

Acknowledgement: NIH RO1 MH-09234

22.23, *11:15 am*

Pre-stimulus activity in inferior temporal cortex gates attentional modulation of neural and behavioral responses.

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Attending to a feature or a point in space enhances neural baseline activity of brain areas representing the attended stimulus. This baseline shift is predictive of the behavior. However, the underlying neural mechanisms of the correlation between baseline activity and behavior has remained unknown. Here we show how the baseline enhancement affects stimulus-evoked responses and how such neural response modulations affect behavioral performance. We recorded single unit responses from inferior temporal cortex of monkeys during both passive viewing and body detection tasks. Depending on the level of task engagement firing rate and variability of the stimulus-evoked responses were modulated. This modulation and subsequently neural response selectivity were larger in trials with high, rather than low, baseline activity. Baseline activity was enhanced just before the stimulus-evoked response, when it maximally affected neural and behavioral performances. The observed baseline contingent changes in neural responses depended on attentional load and cells' stimulus selectivity. These results indicate that attention enhances the baseline activity in an optimal time to improve the task relevant sensory representation and behavioral performance.

Acknowledgement: This research was supported by Institute for research in fundamental sciences (IPM) and Iran National Science Foundation (INSF).

22.24, *11:30 am*

Violation of Bayesian Cue Integration Principle Under Attentional Cuing

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Current dominant theories of perception hold that when faced with multiple sources of information, the human brain weights them by their respective reliability in a near-optimal fashion. Here we present results to show that such principles, though attractive from an engineering perspective, may break down in humans in conditions as common as attentional cuing. In order to account for the finding that attention leads to relatively conservative perceptual decisions, we recently proposed a signal detection theoretic model (Rahnev et al 2011 Nature Neuroscience) which assumes a single read-out mechanism compromising between the different variance structures associated with attended and unattended stimuli. Specifically, the observer sets a common decision criterion for both the attended and unattended, and thus is systematically suboptimal for both. One counter-intuitive prediction of the model is that when subjects try to incorporate prior expectations (e.g. the upcoming grating is 70% likely to be tilted to the left rather than right) into their perceptual decisions, a relatively strong weight would be given to the prior expectation when the stimulus is attended and reliably processed, rather than unattended and poorly processed. This prediction goes against principles of Bayesian optimality, and thus allows for a strong test for our model. We confirmed our a priori predictions. Results from Experiment 1 suggest that perhaps a strong weight is given to the prior when the stimulus is attended, because attention leads to relatively conservative subjective decision confidence compared to inattention, which may bias the weight given to the prior. However, Experiment 2 shows that even when the attended stimulus led to both a stronger objective informational strength (higher d') as well higher decision confidence compared to inattention, subjects still assigned higher weight to the prior. These results pose strong constraints on models of the read-out mechanism in perceptual decisions.

22.25, *11:45 am*

Left parietal patients have impaired salience suppression but only when there is response conflict

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Recently it has been argued that the left posterior parietal cortex (PPC) is particularly important when low-salience targets need to be selected while high-salience distractors need to be ignored (salience-based selection). In particular, in the context of unilateral damage to the parietal cortex it has been shown that left parietal patients are impaired when responding to both local and global aspects of a compound letter stimulus as long as the target level is low in salience and the distractor level has high salience (Mevorach et al., 2006, Neuropsychologia). However, it is not clear whether this is a consequence of competition for perceptual representation or for response

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between target and distractor. In the present study we compared performance of left parietal patients and controls in a salience-based selection task which enabled us to separate competition for response from competition for perceptual representation. Superimposed faces and scenes where used in which either the face or the scene was more salient than the other. In different blocks of trials participants identified the face (ignoring the scene) or the scene (ignoring the face). Faces and scenes were either assigned to competing responses (Exp. 1 - response conflict) or were individually named (Exp. 2 - no response conflict). Interestingly, our left parietal patients were particularly impaired in responding to the less salient target under conditions of response conflict (Exp. 1) while their performance was comparable to that of controls when response competition was eliminated (Exp. 2). The results corroborate previous findings indicating the left PPC is implicated in the suppression of salient irrelevant information. Moreover, our findings suggest that the left PPC is particularly important when irrelevant, salient stimuli elicit a competing response. Thus, it appears that this region is important in an attention and action circuit that prevents us from producing inappropriate actions to salient distractors.

22.26, *12:00 pm*

Eccentricity representation of visual stimulation, attention, and saccades in human superior colliculus

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We previously demonstrated using high-resolution fMRI that polar angle topographic representations of visual stimulation and attention in human SC overlap and are similar to macaque. Here we measure the representation of eccentricity for visual stimulation, attention and saccades. Methods: Visual stimulation was measured using a phase-encoded protocol. Subjects fixate at one edge of the display while an expanding wedge of moving dots (50° polar angle, 2°/s moving dots) was presented for a single hemifield at 6 equally spaced eccentricities between 5—30°. Wedges were divided into four virtual sectors and subjects performed a speed-discrimination task. Visual attention was measured with subjects performing the speed-discrimination task alternately within inner and outer sectors of moving dots (2—5.5° and 10—14°) that were continually present. Experiments with larger field-of-view and four eccentricity ranges are in progress. Saccadic eye movements were measured with blocks of saccades vs. fixation. In saccade blocks, subjects followed a white dot whose position alternated between two sectors in the left and right hemifields (0.6 sec/saccade). In fixation blocks, subjects fixated on a stationary dot within one of the two sectors while performing a dot color-counting task. Distance between the two sectors was varied across fMRI runs to get 3 saccade eccentricity ranges: 7—10°, 15—20° and 26—31° with 6 runs per condition. For all experiments, high-resolution fMRI (1.2 mm voxels, 3-shot spiral) was acquired (3 sec/volume) in 8 slices covering SC (24-sec period, 9 cycles/run). Results: Visual stimulation was represented in the contralateral colliculus with a clear rostral-to-caudal progression with increasing eccentricities. Attention and saccade representation also had a rostro-caudal progression, but saccade representations did not show precise agreement with stimulation. Conclusion: Visual stimulation, attention and saccadic eye movements' representations of eccentricity in human SC all follow a rostro-caudal progression similar to those observed in macaques.

Acknowledgement: Work funded by NSF 1063774

22.27, *12:15 pm*

Distinct patterns of coherent firing for feature binding and selective attention in neurons of the visual cortex

Anne Martin[1](annebmartin@gmail.com), Rudiger von der Heydt[1,2]; [1]Department of Neuroscience, The Johns Hopkins University, [2]The Zanvyl Krieger Mind/Brain Institute, The Johns Hopkins University

The goal of this study is to understand the relationship between feature binding and selective attention at the neural signal level. We recorded neurons with two microelectrodes inserted in macaque areas V1 or V2. The animal performed a delayed shape discrimination task that involved simultaneous processing of two edges of a trapezoid. The animal was cued to perform the task with one or the other of three simultaneously displayed figures. We studied the spike time correlations between neurons, comparing the conditions when two neurons respond to edges of the same figure (binding) versus edges of different figures, and when a figure is attended versus ignored. We analyzed the spike time cross correlation function and its power spectrum. In the ignore condition, we found a peak of correlation in the beta frequency range (~18Hz) when the neurons responded to the same figure (binding). When the neurons responded to different figures, this peak was absent. Attending to the common figure caused a two-fold increase of the peak, but did not affect correlation in the different-figures condition. Binding produced zero time lag spike synchrony across the population of pairs. Under attention, the synchrony was reduced after stimulus onset, but increased towards the end of the delay period. The emergence of correlation with binding and its increase with attention parallel our previous observations on the local field potentials (Martin and von der Heydt, Society for Neuroscience Abstracts 2010). Spike synchrony between widely separated neurons in cortex (3-10mm) indicates a common input. Thus, the emergence of synchrony with binding is consistent with feedback from grouping cells as postulated in Craft et al., J Neurophysiol (2007). The predominance of beta suggests feedback from parietal cortex. Our results show distinct mechanisms for binding and attention which interact because binding provides the structure for object-based attention.

Acknowledgement: NIH R01-EY02966, NIH R01-EY16281, ONR-MURI BAA08-019 , NIH T32-EY07143-13

Saturday Morning Posters

Temporal processing

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

23.301 **Cross Frequency Coupling during the resting state with and without visual input**

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Brain oscillations can be classified into different frequency bands: delta (1-4Hz), theta (4-8Hz), alpha (8-14Hz), beta (14-30Hz), low (30-45Hz) and high gamma (55-80Hz). These oscillations are often studied in isolation, but the interactions between frequency bands may also serve to implement important functions in the brain: for example, integration of sensory information from multiple sources or modalities, consciousness, memory or attention. As a first step to characterize these interactions and their functional roles, we measured phase-amplitude cross-frequency coupling between all EEG scalp locations (64 electrodes) and all pairs of frequency bands, during awake rest with eyes opened or closed (15 participants in each condition). This type of coupling quantifies the dependence of a certain oscillation's amplitude (recorded at a given scalp location) onto the phase of a lower-frequency oscillation (potentially recorded at a different scalp location). When the subjects' eyes were closed, we found a highly significant coupling between the phase of occipital alpha oscillations and the amplitude of the lower-gamma frequency band across all scalp locations (compatible with findings by Osipova et al., PLOS One, 2008). When subjects opened their eyes, this effect vanished and was replaced by a weaker and more local coupling between occipito-temporal alpha phase and oscillatory amplitude, this time in the higher-gamma frequency band. Furthermore, we found significant coupling between oscillatory amplitude of the beta frequency band in occipito-temporal brain regions and the phase of theta-band activity in occipital and fronto-central regions; this effect did not depend much on whether the participants' eyes were opened or closed. These phase-amplitude cross-frequency coupling interactions might help to maintain a specific spatio-temporal excitability pattern in the brain during the resting state. Finally, the dependence of occipital alpha-gamma coupling on visual inputs suggests that these interactions may also contribute (possibly in an inhibitory manner) to normal visual processing.

Acknowledgement: This research was suppported by a EURYI grant and an ANR grant JCJC06-154 to RV.

23.302 **The Temporal Fusion Illusion and its neurophysiological correlates**

Hector Rieiro[1, 2](hrieiro@neuralcorrelate.com), Manuel Ledo[1], Susana Martinez-Conde[1], Stephen Macknik[1]; [1]Barrow Neurological Institute, Phoenix, AZ, [2]University of Vigo, Vigo, Spain

We present a novel visual illusion called "Temporal Fusion". When a visual target, such as a bar stimulus, is flashed twice in succession with an inter-stimulus interval of 100 ms, the two flashes are easily discernible as flicker. We have discovered that these two target flashes are fused perceptually if we present a two-bar mask stimulus that is spatially abutting (not overlapping) the target during the period of time between flashes. Human psychophysical testing on naive observers confirms that the temporal fusion percept is confused with a single long-duration target flash (having an overall duration matching the two flashes in the illusory condition) that is flanked by the mask during its midlife. To determine the neural basis for the illusion we conducted single-cell neurophysiological recordings in area V1 of two awake rhesus monkeys. We confirmed that responses to the temporal fusion illusion closely resemble the responses to the non-illusory long target stimulus that has the same appearance as the illusion. Importantly, the similarity of the responses between the two conditions is specifically strong in the response to the mask's termination. This emphasizes the perceptual importance of responses to stimulus termination, and suggests that stimulus transients from the mask are not only capable of suppressing target transients (as we have previously found in visual masking), but they also play a role in shaping the perception and visibility of surrounding stimuli.

Acknowledgement: Fundacion Ibercaja, Science Foundation Arizona, National Science Foundation, Catholic Healthcare West, Barrow Neurological Foundation

23.303 **Unconscious priming requires primary visual cortex at specific temporal phases of processing**

Marjan Persuh[1](mpersuh@gmail.com), Tony Ro[1]; [1]Department of Psychology and Program in Cognitive Neuroscience, The City College and Graduate Center of the City University of New York

Priming occurs when one stimulus (i.e., the prime) influences the processing of a subsequently presented stimulus (i.e., the target), even when the first stimulus remains unconscious. Although examples of unconscious shape priming have been extensively documented, whether such processing requires primary visual cortex (V1) has not been established. In the current study, we used transcranial magnetic stimulation (TMS) of V1 at varying temporal intervals to suppress the visibility of preceding shape primes while the interval between primes and targets was kept constant. On each trial, we measured reaction times to targets (priming) as well as prime visibility (awareness). Our results show that although conscious perception requires V1, unconscious priming can occur without V1 at intermediate temporal intervals but not at early or later stages of processing. This phasic TMS suppression of priming suggests that there may be visual information processing cycles during which only certain phases robustly represent information within V1. Because the later time window of priming suppression (85 - 105 ms) has been proposed to interfere with feedback processing, our results further suggest that feedback processing is also essential for unconscious priming and may not necessarily be a signature of conscious vision.

23.304 **How does the brain learn about time?**

Domenica Bueti[1,2](domenica.bueti@gmail.com), Stefano Lasaponara[1,3], Mara Cercignani[1,4], Emiliano Macaluso[1]; [1]Neuroimaging Laboratory, Santa Lucia Foundation, Rome (Italy), [2]Department of Clinical Neurosciences, University Hospital, Lausanne (Switzerland)., [3]Department of Psychology, University of Rome 'La Sapienza', Rome (Italy)., [4]Clinical Imaging Sciences Centre Brighton and Sussex Medical School, University of Sussex, (United Kingdom)

How do we discriminate lines of different orientations or that move in different directions? Neurophysiology has answered this question by showing that in visual cortex there are cells selectively tuned to specific lines orientations or moving directions. However, the answer to the equally important question: 'How does the brain discriminate between different durations of a visual or an auditory event?' remains largely unknown. Here we use perceptual learning to investigate the neural representation of temporal information in the millisecond range. Healthy volunteers were trained on a visual temporal discrimination task over 4 consecutive days. Before and after training, participants underwent functional imaging (visual and auditory temporal discrimination tasks) and structural imaging (T1-weigheted and diffusion tensor imaging). Behaviorally, the training procedure improved temporal discrimination thresholds for the 'trained' visual modality. Similar but less consistent effects were also observed for the 'untrained' auditory modality. Enhanced temporal discrimination was associated with increased BOLD responses in the left posterior insula for the visual task, and in the left inferior parietal cortex for the auditory task. After training, the structural data revealed an increase in both grey matter volume and fractional anisotropy in the right cerebellum (Crus1 and VIIIa lobule). Both functional and structural changes were found to correlate with the behavioral changes in performance accuracy. Moreover, we found that functional activation and grey matter volume in medial and lateral sensorimotor cortex before training predicted learning at the behavioral level. These findings represent the first neurophysiological evidence of structural and functional plasticity associated with the learning of time in humans; and highlight the role of the insula and sensorimotor regions for the perceptual representation of temporal durations in millisecond range.

23.305 **A Longer Look at Time: Time Slows Down During Prolonged Eye Contact**

Michelle Jarick[1](majarick@uwaterloo.ca), Kaitlin Laidlaw[1], Vanja Alispahic[1], Alan Kingstone[1]; [1]Department of Psychology, University of British Columbia

Eye contact plays a crucial role during social interactions. It demonstrates that we are engaged, interested, and attending to the people involved. Why then, do we only make eye contact for brief periods of time? One hypothesis is that prolonged eye contact (> 5 seconds) elicits an elevated degree of arousal, which then could be interpreted as intimacy (or intimidation) leading to anxiety in both individuals. Here we investigated whether prolonged eye contact (live or through the computer) could distort our perception of time. In the live condition, two naïve participants made a 1-minute time estimate while sitting next to one another and maintaining three different poses: looked at the wall (baseline), looked at their partner's profile (face averted) or made eye contact with their partner. Over the computer, participants made the 1-minute estimate while watching videos equated to the live poses (i.e., empty room, person's profile, and eye contact). Recent research has shown that subjective time estimates increase (i.e., time slows down) during arousing events. Thus, if eye contact induces a high degree of arousal, then we predicted time would seem to slow down during conditions in which participants made eye contact. Indeed this was the case. We found that participants made significantly longer time estimates when they made eye contact, as opposed to when they looked at another person or just sat next to another person. Importantly, this duration expansion was only observed when participants made eye contact with their partner face-to-face and not with a person in a video. We attribute this difference to an increase in anxiety when looking into the eyes of a person next to you that does not exist over the computer. Thus, we showed that when studied in a natural environment, prolonged eye contact causes time to slow down.

Acknowledgement: NSERC

23.306 **Back to the Future: Recalibration of visuomotor simultaneity perception to delayed and advanced visual feedback**

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Perceived simultaneity is subject to change through recalibration. Thereby, the brain compensates for small temporal discrepancies. This has been shown, e.g., for visuoauditory, visuotactile and even for visuomotor events. Visuomotor recalibration has so far only been investigated for visual stimuli that follow voluntary motor actions. Here we ask whether visuomotor recalibration can occur in both directions, to compensate not only for visual stimuli following a motor action but also for stimuli preceding the action, which violates the underlying cause-effect relationship. To this end, we manipulated the temporal relationship between a motor action (a button press) and a visual event (a flash) triggered by this action. The effect of recalibration to a constant delay of ±100 ms was determined using a temporal order judgment task. Participants' perceived simultaneity (PSS) was compared before and after recalibration. To be able to present visual stimuli before the full compression of the button, the time of this event had to be predicted. This was achieved using a virtual button, displayed with a Phantom force-feedback device, so finger motion could be recorded and analyzed online. An adaptive threshold predictor estimated the moment of the full compression of the button in real-time from early movement onset. We found a significant recalibration of PSS in both the delayed feedback (-16±6ms, SEM) and in the advanced feedback (26±7ms, SEM) conditions ($p<0.05$). Since the prediction method contained some amount of temporal uncertainty, we also analyzed the strength of the recalibration effect as a function of this uncertainty. Interestingly, there was a trend showing less recalibration with increasing temporal uncertainty in the predictor. Taken together these results show that visuomotor recalibrations can occur for both delayed and advanced visual stimuli, irrespective of the causal asymmetry that says visual stimuli that precede a voluntary action cannot be caused by this action.

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23.307 **Separate duration calibration mechanisms for dynamic and static visual stimuli**

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Several seconds of adaptation to a flickered stimulus makes a subsequently presented brief stimulus appear longer if it is static — temporal-dilation aftereffect, but shorter if it is flickered — temporal-constriction aftereffect. We demonstrated orientation specificity, eye selectivity, and insensitivity to adaptation frequency (for 5Hz and 20Hz; current study) for the temporal-dilation aftereffect, whereas others have demonstrated orientation independence, eye selectivity, and selectivity for faster adaptation frequency (20Hz effective but 5Hz ineffective) for the temporal-constriction aftereffect; these results suggested a role of cortical visual adaptation in temporal dilation and subcortical magno adaptation in temporal constriction. However, the two aftereffects were always measured with different methods, temporal dilation with a temporal-bisection task (comparing each test duration with memorized reference durations), and temporal constriction with a sequential-comparison task (comparing the reference duration presented at the adapted location with each test duration presented at a non-adapted location). We directly compared these aftereffects using the same temporal-bisection task to confirm that the dilation and constriction aftereffects reflect separate visual duration mechanisms rather than procedural artifacts. For a static test stimulus, both 5Hz and 20Hz adaptors produced temporal dilation. For a flickered test stimulus, a 5Hz adaptor still produced temporal dilation, but a 20Hz adaptor produced no effect rather than temporal constriction. However, when we measured the effect of the 20Hz adaptor at the adapted and non-adapted locations, perceived test duration was longer at the non-adapted location than at the adapted location, confirming the previous sequential-comparison result that the test duration was perceived to be shorter at the adapted relative to a non-adapted location. Overall, using a single psychophysical method, we demonstrate that flicker adaptation causes differential effects on the perceived duration of static and flickered stimuli, suggesting that the visual system implements separate duration calibration mechanisms for static and dynamic stimuli.

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23.308 **Changes in** visual apparent motion direction by cross-modal interaction are not dependent on temporal ventriloquism

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Previous studies support the existence of a process wherein the apparent timing of audio and visual signals are attracted toward one-another – temporal ventriloquism. In particular, a recent study (Freeman & Driver, 2008, Current Biology) provided a compelling demonstration in which temporally adjacent auditory flankers induced directional apparent motion (DAM) in an ambiguous repetitive visual motion display. This result was interpreted as being consistent with each visual element being drawn across time toward a corresponding auditory flanker, physically shortening/lengthening the temporal interval between successive visual presentations – a temporal ventriloquism account. We were interested in whether the reported effect necessitated the proposed changes in physical event timing. Using a similar stimulus, we first replicated the original effect of cross-modal flanker induced DAM for both audio (A) and tactile (T) flanker types. If the reported DAM effect depends only on changes in physical timing of the visual event, as induced by a cross-modal flanker, the type of flanker should not matter. We sequentially varied flanker type within the repetitive visual sequence (e.g. flanker sequence: A.T…A.T…A.T...) and found that perceived DAM was significantly reduced for both within (Pure-tone and Gaussian noise pulses) and across (A-T) modality flanker pairs. Most interestingly, when flankers were presented synchronously with visual events, and alternated in a pair-wise manner (e.g. A.A…T.T…A.A...), we found that reported DAM was consistent with the directional sequence of a matching flanker pair. For example, if an audio-visual presentation on the left was succeeded by a matching audio-visual presentation on the right, the reported DAM was rightward, despite having no temporal asynchrony. Our results suggest that the original DAM effect cannot be accounted for by a simple cross-modal timing capture account (temporal ventriloquism). We propose an explanation utilising a supra-modal grouping process dependent primarily on temporal proximity and attribute similarity.

23.309 **No cue integration but cue switching in the temporal domain with stimuli exclusively presented in the visual modality**

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Accurate time perception underlies behavioural performance on many tasks: a pedestrian, attempting to cross the road, has to accurately estimate the time when an approaching car will cross his way. Perception of time is limited in accuracy due to internally generated temporal noise or uncertainty (ITU). ITU increases with time interval duration and as such increasingly interferes with behavioural performance. In the non-temporal domain (e.g. depth perception), studies have demonstrated that participants can use multiple cues (visual and tactile information) to improve performance by reducing sensory noise. Does this hold in the temporal domain? Participants completed a time interval reproduction task with a ready-set-go procedure. They received two visual stimuli (READY and SET), separated by one fixed target interval (TI). They were instructed to reproduce the TI after SET. After SET, at a fixed time interval before the correct time for the response (additional target interval: ATI), participants received an additional visual stimulus (AS). AS provided additional information about the correct time for the response. The degree of information depends on ATI duration (short/intermediarte/long); it decreases with increasing ATI duration due to increasing ITU. If participants use ATI, then precision in time interval reproduction should improve, in particular if the degree of information is high (short ATI). We tested whether participants (a) use only SET, (b) use AS and SET, or (c) use only AS for time interval reproduction. We computed expected precision in time interval reproduction for each hypothesis derived from baseline data (time interval reproduction without AS). Results show that participants use only AS. Thus, participants are able to extract information from SET and AS but fail to integrate the temporal information provided by both stimuli. We discuss implication of this failure to cue-integrate for modality-specific models of interval timing and perception of cause and consequence.

23.310 **Spatial cueing and task difficulty effects on the temporal attention selective temporal parietal junction**

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Introduction. Patients with parietal damage often show spatial deficits that are commonly limited to the contralesional field, while temporal deficits are typically bilateral (Battelli et al., 2003). In a previous fMRI study, we found temporal parietal junction (TPJ) activation when subjects attended to temporal features of a dynamic quartet, with the left TPJ activated by attention to both hemifields. Here, we isolate the effects of cueing and task difficulty on the same tasks. Methods. In an event-related fMRI design, subjects viewed a quartet of disks (two per hemifield, 4 deg eccentric) flickering for 1000 ms, sandwiched in time between 350ms of textured disks in the same location. Subjects reported whether the two disks in a targeted hemifield were in phase (flicker task) or identical in contrast (texture task). Flicker rate and texture contrast were calibrated individually to yield 80% performance. Pre-cue trials were initiated by an arrow indicating the target hemifield. The arrow was shown after the stimulus in post-cue trials. In a second experiment, subjects performed the flicker task on an 8Hz flicker quartet with a singleton disk flickering 45, 90, or 180 degrees out of phase (all post-cued). Results. Group analysis revealed a main effect of task, with ventral TPJ regions more strongly responsive to flicker relative to more dorsal regions. This pattern was largely explained by cueing, with a similar TPJ task effect in the pre-cue trials only. For post-cue trials, TOJ selective activation was apparent only in the left hemisphere. The phase manipulation revealed increased activation in left TPJ for more difficult out-of-phase conditions, regardless of attended hemifield. Conclusions. Our findings support left TPJ involvement in attention directed to temporal features, particularly when spatial shifts of attention are controlled. It remains unclear how to reconcile these findings with the patient literature.

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23.311 **The Straddle Effect in temporal contrast processing (Buffy** adaptation) is specific for orientation and spatially local

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INTRODUCTION. Perception of a test pattern composed of two contrasts depends dramatically on the contrast of the adapt pattern immediately preceding it. If the immediately preceding contrast is straddled by the two test contrasts, the test pattern is very difficult to perceive correctly. If, however, the immediately preceding contrast is a bit greater than both the two test contrasts (or a bit less), performance improves dramatically. Here we show that this Straddle Effect (originally nicknamed Buffy adaptation) is spatially local and specific for orientation. METHODS. In the experiments here, the adapt and test patterns were regularly-spaced 2x2 grids of Gabor patches. The adapt-pattern Gabors could differ from the test-pattern Gabors in one of three spatial characteristics: orientation, phase, or exact position. The spatial frequency and size of all Gabor patches were constant throughout. All the Gabors in the adapt pattern had contrast 50%. Two of the four Gabors in each test pattern were at one contrast, and two were at another. The observer had to say whether the arrangement of the two different test contrasts formed horizontal or vertical stripes. The adapt pattern was on for about 1 sec before and after the 100 ms test pattern. RESULTS. When the spatial characteristics of the adapt and test patterns were identical, there was always a Straddle Effect. When they differed in orientation, phase, or position, the Straddle Effect was much diminished. The way the Straddle Effect diminished was NOT that the straddling test pattern became easier to perceive correctly. Rather test patterns having contrasts both a bit above the adapt contrast (or both a bit below) became much harder to perceive correctly. DISCUSSION. Perhaps the contrast comparison process proposed to account for the Straddle Effect occurs at the output of something as localized as a V1 receptive field.

23.312 **How long depends on how fast – perceived flicker frequencies dilate subjective duration**

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When a stimulus changes over time, its duration is subjectively dilated. It is unknown whether the dilation of dynamic stimuli is caused by automatic processing of the stimulus, or is based on higher level processing that requires conscious awareness of the change. We manipulated stimulus dynamics and their conscious perception by presenting flickering light with frequencies below and above the flicker fusion threshold (i.e. the highest frequency still consciously perceived as flickering). We used LEDs mounted in a custom-built binocular flicker-goggle while recording EEG from 64 electrodes, to stimulate participants' visual field with light flickering at a broad range of frequencies (8 -166 Hz). By recording steady state visual evoked potentials (SSVEP), we found a range of frequencies, which were not consciously perceived as flickering, but still evoked SSVEP over occipital cortex (45 – 70 Hz). We also assessed subjective duration of the same stimuli in a two alternative forced choice task, in which participants compared the duration of the flickering stimuli to the duration of a static standard stimulus. Our results show that only stimuli that were consciously perceived as flickering were judged longer than the quasi-static reference stimulus. We found an inverse linear relationship between flicker frequency and perceived duration: the extent of overestimation decreased with higher frequencies. However, overestimation disappeared for frequencies above the flicker fusion threshold, even if those frequencies still evoked SSVEP. In conclusion our findings suggest that conscious perception of stimulus dynamics, such as temporal frequency, is driving subjective time dilation.

23.313 **Neural mechanisms of action recognition and implied motion**

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Problem. Evidence suggests that cells exist in cortical area STS which are selective to the motion of animate objects and show an increase in activity when characteristic poses of the corresponding temporal sequence are presented [Jellema & Perrett, Neurophysiologica 41, 2003]. In addition, activities in MT/MST are enhanced when still images with implied motion are presented [Kourtzi & Kanwisher, J. Cogn. Neurosci.13, 2000]. It is still unclear how and to which extent form and motion information contribute to the generation of the underlying mid-level visual representations. Method. We propose a neural model consisting of two separate processing pathways for segregated form and motion processing extending work by Giese & Poggio [Nat. Rev. Neurosci.4, 2003]. Prototypical form representations (area IT) and optical flow patterns (area MST) are learned using a competitive Hebbian learning scheme with a trace mechanism. The activities of form and motion prototypes converge in area STS where their temporal correlations are learned by a combined bottom-up and top-down learning. Top-down weights establish a prediction mechanism enabling the sequence selectivity of the STS cells. A modulatory mechanism which favors prototypes co-occuring with local minima in the motion energy is responsible for the selection of key poses in a sequence. For the signature

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of walking this condition is satisfied for strongly articulated body poses. Results and Conclusion. The proposed model is capable of learning action sequences and suggests convergent form-motion interactions in action and activity recognition. Learning is driven by realistic input sequences and their processing along the different model pathways. After learning, form-driven bottom-up input activation leads to increased activation of STS cells. Motion driven MST and STS cells show an activation even if there is only form information present in the signal thus giving an explanation of the neural basis of implied motion in vision.

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23.314 **Time estimation in perception and anticipatory action**

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A reliable perception of the time a moving object takes to travel between two points in space is important to organise our behaviour in dynamic environments. It is intuitive to suggest that the temporal estimates regarding the same visual input engage similar mechanisms. This study sought to determine whether our perceptual judgements of the passage of time of a moving object and the estimation of time-to-arrival of this same object in an anticipatory action use the same metrics. To achieve this we employed a motion adaptation protocol known to cause localised distortions of the conscious perceptual experience of time. Consistent with previous reports, the results indicated that we succeeded in inducing a reduction of the perceived duration in the locations adapted to a fast moving stimulus but not to a slow moving stimulus. Moreover, we find symmetrical effects of motion adaptation on the timing of anticipatory interceptive actions, which are paralleled by changes in perceived speed. These results suggest that the temporal metrics for time perception and anticipatory actions depend on different mechanisms or processes.

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23.315 **Slowing down appears to last longer than speeding up.**

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The speed of a visual stimulus has been shown to influence its apparent duration: for low speeds, faster stimuli tend to be judged as longer (Kanai, Paffen, Hogendoorn, & Verstraten, 2006, Journal of Vision, 6, 1421-1430; Kaneko & Murakami, 2009, Journal of Vision 9, 14). This effect has been ascribed to the number of changes that occur within a visual interval. Intervals that contain more changes (i.e., faster intervals) are likely to show time dilation. If this is true, we should not expect to find specific differences in perceived duration for intervals that contain the same number of changes. In this study, we measured the apparent duration of drifting gratings whose speed continuously increased (acceleration) or decreased (deceleration) linearly around an average value (10 °/s). Note that the two conditions (acceleration, deceleration) have the same number of cycles. Subjects had to compare accelerating or decelerating stimuli with comparison stimuli of variable duration that drifted at a constant speed (also 10 °/s) in order to determine a psychometric function. Six speed pairings (from 0-20 to 10-10 °/s) and three standard durations (300, 600 and 900 ms) were investigated. We observed a clear difference between the two conditions. While the perceived duration of the decelerating stimuli showed a mild expansion that did not depend on the rate of deceleration, the accelerating stimuli showed a strong compression, which increased with the rate of acceleration. Duration discrimination thresholds (estimated from the slopes of the psychometric functions) were indistinguishable between the acceleration and deceleration conditions and did not show any dependence on the rate of acceleration or deceleration. Our results cannot be explained by a mechanism that simply reflects the number of temporal features within an interval in determining the perceived passing of time.

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23.316 **Temporal Limit for Individuation of a Face**

Faraz Farzin[1](ffarzin@stanford.edu), Anthony Norcia[1]; [1]Department of Psychology, Stanford University

Psychophysical studies have shown that temporal processing is capacity-limited and that the limit may depend on the stage of processing used for encoding. For example, perception of flicker has a temporal limit of 30-80 Hz, whereas identification of the individual states of flicker has a lower limit of 7-10 Hz. Here, we investigated the temporal limit for individuation of a face using steady-state visual evoked potentials (ssVEPs). The ssVEP method is ideal for measuring temporal processing because responses evoked by the transition between visual events occur at frequencies that are exact multiples of the alternation rate. Stimuli comprised a phase-scrambled and an intact face image alternating at a fixed temporal frequency. Face-specific responses occurred at the odd harmonics of the alternation rate. Stimuli were presented at four locations centered on fixation. The images at the "target" location flickered 180° temporally out-of-phase with those at the other three locations. High-density EEG was recorded while 10 adult observers performed a phase-judgment task identifying the "out-of-sync" location. Thresholds were defined as the temporal frequency yielding 62.5% correct performance. Perceptual limits for face individuation ranged from 2.95-6.31 Hz (M = 4.33 Hz, SD = 1.34). A vector average of the first harmonic response was calculated for electrodes over left, right, and medial occipital regions, for each temporal frequency. All observers showed decreasing responses as a function of temporal frequency, independent of electrode region, and responses were positively correlated with performance. Linear extrapolation of individual amplitude curves produced ssVEP limits ranging from 4.33-18.58 Hz (M = 10.47 Hz, SD = 4.02), consistent with the low perceptual limits. Together these results support the theory that perceptual access to visual information processed at higher stages is limited to slow temporal rates, and demonstrate that ssVEP is a valid tool for measuring temporal limits.

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23.317 **Self awareness induces distortion of time perception**

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As one of the most self-referential stimuli, one's own name seems to be particularly prone to seize attention due to its intrinsic personal significance. Although it has been well documented in the auditory domain, how the processing of self-related information interacts with visual attention remains controversial. Here we report a self-induced perceptual distortion of time perception. In a temporal discrimination task, we found that the visual presentation duration of the participant's own name was perceived significantly shorter compared with that of a stranger's name of equal physical duration. Critically, this duration underestimation was not due to the familiarity of the own name, as a famous name showed no such effect when compared with a stranger's name. Moreover, this temporal underestimation effect can also be observed with the self-face stimulus, suggesting a special role of self awareness in attentional modulation of time perception.

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Motion: Higher Order

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

23.322 **Effects of Aging on the Integration of Inter- and Intra-modal Motion Cues**

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When two objects move toward one another, motion at the point of overlap is ambiguous: the objects may stream past one another or bounce off one another. A sound presented around the time of coincidence biases the percept toward bouncing (Sekuler et al., 1997, Zhou et al., 2007). In contrast, a visual occluder that obscures the motion coincidence biases the percept toward streaming (Sekuler and Sekuler, 1999). Because multisensory integration changes with age (Peiffer et al., 2007, Stephen et al., 2010), we exploited the bouncing-streaming percept to assay age-related changes in the integration of multiple inter- and intra-modal cues. We also examined the temporal development of occlusion by determining the percept for occluders of different durations. In 12 interleaved conditions, younger (n=9; mean age=20) and older (n=9; mean age=68) subjects judged whether two moving gray discs bounced or streamed. The discs were presented on their own (control), or accompanied by a sound, an occluder of varying duration, or both sound and occluder, all centered around the time of the discs' coincidence. On half the trials, the discs differed in luminance (producing unambiguous streaming or bouncing in control conditions); on other trials, the discs had equal luminance (producing an ambiguous percept in control conditions). Younger, but not older, subjects showed a significant bias toward streaming responses in the ambiguous, control condition. A sound at the point of coincidence biased the percept toward bouncing in both groups, but its effect was reduced in older subjects. The effect of occluders depended on duration: brief occluders promoted bouncing in younger subjects, but not older subjects, whereas long occluders promoted streaming in both groups. The weakened inter- and intra-modal integration seen here could contribute to previously demonstrated age-related deficits in memory, and may be linked to age-related changes in neural processing in the gamma band

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23.323 **Neural correlates of non-retinotopic motion integration**

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Under normal viewing conditions, due to the motion of objects and to eye movements, the retinotopic representation of the environment constantly changes. Yet we perceive the world as stable, and we easily keep track of moving objects. Here, we investigated the neural correlates of non-retinotopic motion integration using high-density EEG. We used a Ternus-Pikler display to establish either a retinotopic or non-retinotopic frame of reference. Three disks were presented for 250 ms followed by an ISI of 150 ms. The disks then reappeared either at the same location (retinotopic reference frame), or shifted sideways (non-retinotopic reference frame). After another ISI, the sequence started over again. In the middle disk, a dot was either changing positions across frames in a rotating fashion, or stayed in the same position. Every 5th to 9th frame, the dot started or stopped rotating, and observers reported this with a button-press. We found higher EEG responses for rotating than static dots. This effect occurred rather late (>200 ms), i.e. after basic stimulus encoding (P1 component). Importantly, these results hold for both the retinotopic and the non-retinotopic conditions, indicating that the encoding of rotation does not depend on reference frame. In line with this, reference frame effects were observed at earlier latencies and did not interact with rotation effects. Electrical source imaging showed that the underlying neural processing of this non-retinotopic effect seems to be located partially in extrastriate visual areas.

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23.324 **A synchronous surround increases motion sensitivity**

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Motion sensitivity is often measured using random-dots: some dots (signal) move to the left or to the right while the remaining dots (noise) randomly change position every frame. Sensitivity is estimated as the minimum proportion of signal-dots needed for the observers to discriminate the direction of motion. Although this task is considered to depend on the signal-to-noise ratio, last VSS (Linares, Motoyoshi, Maruya, & Nishida, 2011) we reported that motion sensitivity is doubled when a task-irrelevant surround is presented in synchrony with the motion target. Here, we report some new findings. First, the motion enhancement does not occur when the motion target and the surround are presented for more than about half a second, which suggests that the increase in motion sensitivity occurs at the onset and offset of the stimulus. Second, the motion enhancement is maintained for relatively large separations between the motion target and the surround (about 6 deg), which suggests the involvement of neurons with large surround-suppressed areas like those found in MT and MST. Third, motion sensitivity is enhanced when the surround is composed of one-dimensional bars displayed orthogonally to the direction of motion but not enhanced when the bars are displayed parallel to the direction of motion. In this last situation, the distance of each dot to the bars remains constant during the motion trajectory, which indicates that relative-motion processing is needed to boost motion sensitivity. Our findings support a mechanism that assists the perception of sudden updates of scenes that include a change in the surrounding context, a common situation faced by observers living in dynamic environments.

Acknowledgement: Beatriu de Pinós fellowship.

23.325 **Periodic motion trajectory detection: Effects of frequency and radius**

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Static radial frequency (RF) patterns (Wilkinson et al., Vision Research, 1998) have proved a useful tool for studying the combination of local and global processes underlying shape discrimination. Or et al.'s (JOV, 2011) investigation into detection sensitivity for temporal RF defined motion trajectories (RF 2 – 5) yielded a similar pattern of sensitivity increasing with radial frequency over this range, but with higher thresholds overall. The current study extended our investigation of parallels between spatial contour and temporal trajectory analysis by examining detection thresholds for higher RF trajectories and for a range of trajectory radii. Amplitude thresholds for detection of non-circular trajectories were measured in a 2IFC paradigm (circular vs. RF trajectory) using the method of constant stimuli. In Exp 1, thresholds for RF3, RF6, RF9, and RF12 were assessed for trajectories of 1 deg radius in 8 observers. Thresholds for the detection of RF 3 trajectories were significantly higher than thresholds for RF 6-12 [$F(3,21) = 65.36$, $p<0.0001$], which approached an asymptotic value of 0.4 min of arc. In Exp 2 (N=4), radii of 2° and 4° were examined for the same RF range. Detection thresholds increased with trajectory radius at all RFs tested. Described as a proportion of the radius (Weber fraction), thresholds were very similar across a 4-fold range of radii, suggesting trajectory shape constancy at threshold. Our findings replicate the results of Or et al. (2011) at RF3, and demonstrate that, as is the case for static RF patterns, thresholds for trajectories approach asymptote for RFs between 6 and 12 cycles, and show a constant Weber fraction for radii up to at least 4°. Although overall thresholds are higher by a factor of 2-6 than for static RF patterns, these similarities suggest that analogous global processing mechanisms may exist in the spatial and spatio-temporal domains.

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23.326 **Interactions of depth order and numerosity in transparent motion**

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In transparent motion the depth order of the two surfaces is ambiguous. However there are sustained biases to see certain directions in the back and others in the front (Mamassian & Wallace, Journal of Vision, 2010). Recently we showed that there are also biases to see the surface that contains more dots in the back (Schütz, Journal of Vision, in press). Here we investigated how motion direction, depth order and numerosity interact in transparent motion. We presented two overlapping random dot kinematograms (RDK) for one second within a circular aperture of 10 deg radius on a uniform gray background. The RDKs were moving along cardinal or oblique directions, with the two directions separated by 45 deg. The overall dot density was fixed at one dot/deg^2 and we manipulated the distribution of dots to the two RDKs in ratios from 0.2 to 0.8. In separate sessions observers were asked to indicate the direction of the surface containing more dots or the direction of the surface perceived in the back. We replicated the finding that the surface containing more dots tends to be seen in the back. Furthermore there were strong directional biases for numerosity judgments as well as for depth order judgments. These directional biases for numerosity and depth order judgments were highly correlated within observers. Thus directions that were more likely to be perceived in the back, were also more likely to be perceived as more numerous. These results indicate that there is either a bidirectional interaction of perceived depth order and perceived numerosity or that both perceptual aspects are influenced by a third, common factor. One such possibility would be that the visual system implicitly adjusts the perceived numerosity of the surface in the back, in order to compensate for the occlusion by the front surface.

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23.327 **How many motion directions can be simultaneously perceived?**

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Previous research indicates that the maximum number of motion signals that can be simultaneously perceived is 2, if they are defined only by direction differences, or 3 if they also differ in speed or depth (VisRes 2006, 2615-2624). Those previous studies used transparent, spatially-sparse stimuli. Here we investigate this motion-number perception limit using spatially-localised stimuli that drive either the standard or form-specific motion systems (VisRes 2009, 429-438). Each motion signal was defined by four signal-dots that were arranged in either a square pattern (Square condition), to drive the form-specific system, or a random pattern (Random condition), to drive the standard motion-system. A temporal 2AFC procedure was used with each interval (180ms duration) containing n or n+1 signals. The observer had to identify the interval containing the highest number of signals. The total number of dots in each interval was kept constant by varying the number of noise dots (dots that started off in the same spatial arrangement as the signal dots but then each of those dots moved in different directions). A mask was used at the end of each motion sequence to prohibit the use of iconic memory. In the Square condition, up to 5 directions could be simultaneously perceived, and only 1 in the Random condition. Decreasing the number of noise dots improved performance for the Random condition, and increasing it decreased performance in the Square condition. These results show that the previously observed limit of 3 is not a universal limit for motion perception and further, that signal-to-noise limits are a fundamental factor in determining the number of directions that can be simultaneously perceived. Hence the greater sensitivity to motion of the form-specific system makes it well suited to extracting the motion of multiple moving objects.

23.328 **Efficiency of object motion extraction using disparity signals**

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Many objects deform when moving and are often partially occluded, requiring observers to integrate disparate local motion signals into coherent object motion. To test whether stereo information can help do this task, we measured the efficiency of extracting purely stereo-driven object motion by comparing tolerance of deformation noise by human observers to an optimal observer. We also compared the efficacy of global shape defined by stereo-disparities to the efficacy of local motion signals by presenting them in opposition. Stimuli consisted of 3-D shapes defined by disk-shaped random-dot stereograms uniformly arranged around a circle, varying randomly in stereoscopic depth. The disparities were oscillated to simulate clockwise or counterclockwise rotation of the 3-D shape. Observers performed a 2AFC direction discrimination task. The mean shape on a trial was constructed by assigning random depths to the disks (Shape Amplitude). The shape was dynamically deformed on every frame by independent random depth perturbations of each disk (Jitter Amplitude). Observers' percent-correct discrimination declined monotonically as a function of Jitter Amplitude, but improved with Shape Amplitude. Observers were roughly 80% as efficient as the optimal shape-matching Bayesian decoder. Next, on each frame, we rotated the shape by 80% of the inter-disk angle, resulting in 2-D local motions opposite to the global object motion direction. Observers' performances were largely unaffected at small dynamic distortions, but favored local motion signals at large dynamic distortions. Our original stimuli were devoid of monocular motion information, hence observers had to extract stereo-defined 3-D shapes in order to perform the task. These stimuli simulate disparity signals from both 3-D solid shapes and transverse-waves viewed through fixed multiple windows. Thus, our results provide strong evidence for the general role of 3-D shape inferences on object-motion perception. The cue-conflict stimuli reveal a trade-off between local motion and global depth cues based on cue-reliability.

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23.329 **Global motion persists when local motion signals are canceled between color and luminance**

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While several studies demonstrated chromatic input to motion processing, it is still under debate what way this chromatic input interacts with luminance-based motion signals. Because motion perception can be canceled by superimposing oppositely moving color and luminance gratings, color motion is thought to be summed with luminance motion at some stage of visual motion processing. To determine at what stage this summation occurs, we investigated effects of motion cancellation on motion integration. The stimulus we used was a translating diamond whose corners were hidden by implicit occluders. Subjects saw only the edges of the diamond following a rotary trajectory. Thus, integration of local motion signals across edges was needed to detect the global motion. Instead of sinusoidally moving bars, we used a locally motion-canceled stimulus for each edge. This stimulus consisted of superposition of luminance and color gratings drifting at the same temporal frequency in opposite directions and canceling the local motion signal of each other. The color grating was produced by anti-phase modulation of the red and green CRT phosphors with their amplitudes set at equiluminance. The contrast of the luminance grating was set to null the local motion the color grating conveyed. Subjects pressed a button when the translating diamond they perceived reached the highest point of the rotary trajectory. These responses ranged around the theoretical timing when the global diamond based on local luminance motion should hit the highest point of the trajectory. Note that at this theoretical timing, the global diamond as predicted from local color motion should hit the lowest point of the trajectory. Therefore, a global motion consistent with the luminance motion signals was still perceived even when they were locally canceled by the color motion. These results suggest that color and luminance motions are not summed before entering the process of motion integration.

Acknowledgement: This study was supported by JSPS Funding Program for Next Generation World-Leading Researchers (LZ004).

23.330 **The flash-lag effect is reduced in patients with cerebellar atrophy**

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The cerebellum is known to implement predictive forward models for the motor system (Wolpert et al. 1998). These models generate spatiotemporal predictions about the consequences of motor commands to aid in the control of movements. Similar spatiotemporal prediction may be involved in overcoming transmission delays in the visual system, e.g. for more accurately perceiving the positions of a moving object. Two possible examples of a spatiotemporal prediction in visual perception are the flash-lag effect, in which a moving object is seen ahead of a co-localized flash (Nijhawan 1994), and the De Valois effect, in which stationary drifting Gabors are perceived as shifted in the direction of internal motion (De Valois & De Valois 1991). Here, we test the hypothesis that the cerebellum also contributes to the generation of spatiotemporal predictions in the visual system. Four patients with cerebellar ataxia due to degenerative cerebellar atrophy and six healthy control subjects were tested on both effects. For the flash-lag effect, they judged the perceived position of a flashed bar in relation to another bar moving towards the fovea in a 2-alternative forced-choice (2AFC) task. For the De Valois effect, we presented Gabor patches arranged vertically and drifting in opposite directions. Patients and controls judged the perceived alignment in another 2AFC task, while the physical alignment was varied. Cerebellar patients showed typical spatial shifts for drifting Gabors in the De Valois effect. However, patients showed, on average, a markedly reduced flash-lag effect compared to controls. Sensitivity (i.e., the slopes of psychometric functions) was reduced for both tasks in patients. These results provide initial evidence that the cerebellum is involved in the spatiotemporal perception of moving object trajectories (in the flash-lag effect), but not in motion-induced spatial shifts of stationary objects (in the De Valois effect).

23.331 **Social cues help us construct the causal perception of physical events**

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In simple mechanical events, our visual system is able to automatically infer the causal stucture of events and yield causal impressions. Physical cues (especially spatiotemporal features of the display) are found to be the key factors of the causal perception. Here we demonstrate that cues of a completely different domain – the social cues -- also impact the causal perception of physical events: the causally ambiguous events are more likely to be perceived as causal if the faces super-imposed on the objects change from neutral to fearful. This effect has following three major properties: (1) the effect is caused by the social information, because it disappears when the faces are inverted or when the expression-changes are unreasonable; (2) merely the change of basic physical features, such as color and shape, can not influence the causal perception; (3) the social cues are integrated in

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a temporal window different from physical cues; (4) the social cues impact the perception process rather than the decision process as the impact also appears in the causality-induced illusion. These findings suggest that the visual system also relies on social information to infer the causal structure of the physical world.

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23.332 When two causes compete for the same effect: How the visual system deals with different streams of event.

Florent Levillain[1](flevillain@mac.com); [1]Psychological and Brain Sciences, Johns Hopkins University

In an attempt to uncover some of the rules governing event perception, we designed a case of causal competition in which two events can both be perceived as causing a third event. A launching effect occurred when a red disc (B), after being contacted by a black disc (A), started to move immediately with the same speed and in the same direction as A. In the same sequence, a pulling effect could manifest when a purple square (C), placed bellow B, initiated its movement just before B, and moved in unison with it for a certain duration. Thus, A and C competed to be considered as the cause for B's movement. To weaken or give strength to one of the possible causal representations, we varied the delay separating A and B's trajectories, as well as the distance covered by C. We asked observers to determine which of the two potential causes, launching or pulling, was the most compelling, or if none of them was striking. We found that the launching effect was dominant for most of the distances travelled by C. However, this dominance tended to recede when a sufficient delay was introduced at the time of collision. Ultimately, the transition from a launching representation to a pulling representation took place when the delay separating the two components of the launching sequence was equal to 300 ms and when C covered half of B's total distance. The dominance reversed completely in favor of an impression of pulling when C accompanied B until B stopped. These results expose a “phase transition point”, when the amount of evidence in favor of a cause supersedes the evidence in favor of the other. They gesture towards a study of the specific inferences drawn to process the temporal and causal order of a scene.

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Decision making

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

23.401 Risk Averse Visual Decision Making Model

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The human visual system has a remarkable ability to decide between multiple targets for fixation in complex perceptual environments. Evolution has refined this process to be both rapid and cheap, allowing over 100,000 saccades to be made every day. Previous work on modeling visual decision making emphasized value maximization and saliency. A recent study by Navalpakkam et al. combined these strategies, suggesting that expected value (EV) computed from the probability of target presence and the magnitude of target reward offered the best performance in modeling human behavior. However, EV strategies are often insufficient in modeling human preferences as individuals tend to exhibit a risk averse (RA) decision making strategy due to decreasing marginal utility for most types of reward. We propose an alternative model for visual decision making, maximizing utility as opposed to value under the decreasing marginal utility assumption. To test our model, we asked 10 UCSD graduate students to participate in a visual decision making experiment. Each trial consisted of a central fixation display, followed by a brief 500 ms presentation of two targets. Subjects were instructed to saccade to the target they perceive will maximize their reward during the stimulus presentation, and a feedback screen is displayed. Each target had the same expected value, but different variance. Risk averse subjects should choose the lower variance target, while the EV strategy will tend to choose the target with the highest recent average reward (and hence can perform above chance, even though the long term EV is equal). Our results show that the risk averse model significantly outperforms the expected value model ($p < 0.0001$) in predicting human fixation location. This suggests that the dynamic decision-making of eye-movements are influenced not only by the expected value of reward, but also the variance of the reward distribution.

23.402 The relation of decision-making and endogenous covert attention to sampling-based neural representations

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Empirical evidence suggests that the brain during perception and decision-making has access to both point estimates of any external stimulus and to the certainty about this estimate. This requires a neural representation of entire probability distributions in the brain. Two alternatives for neural codes supporting such representations are probabilistic population codes (PPC) and sampling-based representations (SBR). We examined the consequences of an SBR and its implications in the context of classical psychophysics. We derive analytical expressions for the implied psychophysical performance curves depending on the number of samples collected (i.e. the stimulus presentation time), which constitute the theoretical limit for optimal performance. This time-dependence allows us to contrast SBR with PPC, in which probability distributions are represented explicitly and near-instantaneously as opposed to successively over time as for sampling. We compared our predictions with empirical data for a simple two-alternative-choice task distinguishing between a horizontal and a vertical Gabor pattern embedded in Gaussian noise. Recasting the decision-making process in the sampling framework also allows us to propose a new computational theory for endogenous covert attention. We suggest that the brain actively reshapes its representation of the posterior belief about the outside world in order to collect more samples in parts of the stimulus space that is of greatest behavioral relevance (i.e. entails rewards or costs). We show that compared to using the veridical posterior, the benefit of such a mechanism is greatest under time pressure - exactly when the largest effects due to endogenous attention have traditionally been seen. We present experimental data for a task in which attention has been manipulated by varying the behavioral relevance of two stimuli concurrently on the screen, but not their probabilities as traditionally done.

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23.403 Using decision models to study the time course of visual recognition

Imri Sofer[1](imrisofer@gmail.com), Thomas Serre[1]; [1]Brown University

Primates' ability to recognize objects in natural scenes is remarkable. As exemplified by rapid stimulus presentation paradigms, the visual system is both fast and accurate. Computational models have been proposed that predict the level of performance of human participants and how recognition may be affected by visual properties of images. However, these computational models do not make any predictions about reaction times, and cannot explain the time course of information accumulation in the visual cortex. Here we present an initial attempt to fill this gap using a decision model that allows for analysis of both behavioral responses and decision times within a unified framework. Participants performed an object recognition task in natural scenes using a backward masking paradigm with varying stimulus onset asynchrony (SOA) conditions. We estimated decision-related parameters for the task using a hierarchical drift diffusion model, an extension of the most widely used decision model. We examined how the drift rate, a parameter associated with task difficulty, can be used to explain the results, and show that changes in the drift rate alone does not seem to account for the distribution of reaction times under different masking conditions. Interestingly we find that both the SOA and image properties affect the variance of the drift rate, and that this change does not seem to simply reflect variability in the stimulus properties across conditions. We speculate that it may reflect multiple processing strategies employed by the visual system to process information. Our results suggest that decision models may constitute a promising tool for understanding the brain mechanisms underlying object recognition.

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23.404 Individual differences in working memory capacity predict the speed of perceptual decision making

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The ability to make rapid and accurate decisions regarding the importance of incoming visual information is a fundamental component of visual cognition. Perceptual decision making (PDM) is typically characterized as a process where information about a stimulus is accumulated until a decision threshold is reached and a response is produced. The integration of sensory evidence over time requires some form of temporary storage buffer, presumably working memory (WM). However, it is unclear whether mechanisms of PDM draw on the same mnemonic resources that determine individual differences in visual WM ability. To examine this possibility, we asked subjects to report the direction of a variable-coherence random dot kinetogram as quickly and as accurately as possible. We fit behavioral performance to the Linear Ballistic Accumulator model (LBA; Brown & Heathcote, 2008). The use of a formal quantitative model is critical because typical behavioral measures (e.g., response latency and accuracy) only capture the final output of the decision process. Quantiative models such as the LBA, however, allow one to quantify latent aspects of PDM, including the speed at which sensory information is integrated (i.e., drift rate), and the total amount of information needed before a decision is made (i.e., response threshold). Our results indicate that individual differences in WM capacity (quantified via performance in separate change detection task and recall tasks) are positively correlated with individual differences in drift rates (r = 0.44; N = 41). Supplemental analyses show that this relationship cannot be explained by individual differences in subjects' response thresholds or mean response latencies. Thus, our findings suggest that individual differences in visual WM capacity predict which subjects are most efficient at integrating incoming sensory information.

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23.405 **Contributions of signal strength and reliability to performance and confidence**

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In perceptual decision tasks, participants have to choose between several interpretations of noisy sensory input, and their performances reflect different types of uncertainty about the stimulus. For instance, in a motion discrimination task where participants have to decide whether a random dot motion stimulus moves primarily on one side or the other of a reference direction, performance is affected independently by the mean and the standard deviation of the distribution of dot motion directions. Here, these two parameters may correspond to two different sources of uncertainty: the latter is about how precise the estimate of the net motion direction is (signal reliability), while the former is about the relative position between this estimate and the midpoint separating the two choices (signal strength). In the present study, our goal is to assess how these two forms of uncertainty impact on observers' confidence about their choices, and whether confidence judgments are following expected performance, as predicted by signal detection theory, or rather are more sensitive to one particular source of uncertainty. Using adaptive methods, we kept observers' accuracy constant while varying conjointly the mean and variability parameters, and we collected confidence judgments in both an objective and a subjective manner. This approach allows us to assess 1) the similarity between subjective and objective measures of confidence judgments, and 2) whether confidence follows preferentially signal strength, signal reliability, or rather the expected performance resulting from both quantities. Preliminary results suggest that observers feel more confident in responding to stimuli that lead to better performance, as expected, but also that observers tend to prefer stimuli that provide greater signal reliability, even when the influence of performance is accounted for. On the methodological side, it appears that the objective measure of confidence is also a better predictor of choice accuracy than the subjective measure.

23.406 **Attentional capture in an online decision-making task**

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Attentional capture refers to the increase in reaction time in visual search when an irrelevant, but salient distractor is simultaneously present. Recent ERP studies have challenged the idea that attention was captured by the salient item: A marker of attentional selection, the N2pc, was observed in response to the search target, but not in response to the salient distractor. Alternatively, it may be that the N2pc is not sensitive enough to measure shifts of attention to irrelevant stimuli. We devised a task in which a search display was shown AFTER observers had initiated a reaching movement toward a touch screen. In a display of vertical bars, observers had to touch the oblique target while ignoring a color singleton. Because the hand was moving when the display appeared, reach trajectories revealed the online decision-making of the participants. We observed that salient, but irrelevant stimuli changed the reach trajectory at the same time as the decision to move toward the target was taken, about 205 ms after movement onset. The change in direction was corrected after another 147 ms. In a second experiment, we compared online decisions to color and orientation targets and observed that the decision to move toward the target occurred earlier for color targets. Salient stimuli support faster decisions than less salient stimuli and may therefore capture attention.

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23.407 **The Vancouver Roulette test: a new measure of decision-making under risk**

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Background: Neurological disorders may impair decisions involving reward, leading to behaviours such as pathological gambling or excessively risk-averse attitudes: this creates a need for clinical tests to assess different aspects of risky behaviour. Objective: Our aim was to create a realistic test of decisions "under risk" (i.e. when probabilities and sizes of the sums involved are known) with each chance of a win offset by the possibility of loss. We examined thresholds determining when healthy subjects are willing to engage in risky behaviour, and how confidence in a prospect changes with expected value. Methods: 17 healthy subjects were presented with a 'roulette wheel' scenario, with varying probabilities and reward magnitudes. The wheel depicted the probability of winning, ranging from 0.2 to 0.8, while a numeral depicted the payout, ranging from 0.8 to 3.2 times their bet. Subjects could decline to play or choose to bet 1 to 3 coins. If they did not win, they lost the sum bet. The dependent variables were the proportion of times when subjects chose to bet 1 or more, 2 or more, or 3 coins. At the end, subject received their winnings. Results: The 50% threshold for participation occurred at an expected value of -0.21 (i.e. on average subjects would lose 20% of their bet). The willingness to bet more coins was a linear function of expected value, with an increase of expected value of 0.45 per added coin. Secondary analyses showed that subjects were twice as responsive to changes in expected value generated by altered probability than to changes from altered magnitude. Conclusion: Our paradigm shows a slight risk-prone tendency in healthy subjects, a linear increase in the confidence of the gamble as a function of expected value, and greater influence of probability than magnitude information in decisions under risk.

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23.408 **Decision-making in visual working memory**

Benjamin Pearson[1](b.pearson@ucl.ac.uk), Paul Bays[1], Masud Husain[1]; [1]Institute of Cognitive Neuroscience, University College London, UK

Recent research in visual working memory (WM) has focussed on patterns of errors in change detection, clarifying the limits on WM maintenance. But there has been far less interest in what reaction times (RTs) on such tasks might reveal about the mechanisms of memory retrieval. For human and primate perceptual judgements, careful study of RT and choice has found evidence of neural accumulators that weigh up stimulus information to select a response. To test if similar decision mechanisms might support retrieval from VWM, eighteen subjects viewed, in different experiments, sets of colored squares or oriented lines and reported the direction of change in position or orientation when one item reappeared after a delay (a design previously reported in Bays & Husain, 2008). The number of items (N) and change magnitude (Δ) were manipulated in a full factorial design. For both tasks, RT increased as Δ was reduced. RT also increased with set size, with the largest changes taking place at small N. The shape of RT distributions within conditions was consistent with a decision process featuring competing linear accumulators. According to this model, the effect of N and Δ was to change only the evidence available to the decision process (μ), and not decision threshold. Echoing previous results for memory precision (Bays & Husain, 2008), μ followed an inverse power relation to N. In fact

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μ was linearly related to memory precision for all judgements difficulties (Δ). In summary, the results support a flexible resource model of WM in which item features are stored in noisy representations, from which competing neural processes accrue evidence to form decisions. Bays, P. M., & Husain, M. (2008). Dynamic Shifts of Limited Working Memory Resources in Human Vision. Science, 321(5890), 851-854.

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23.409 Contributions of Sensory Precision and Learning Rate to the Optimality of Dynamic Criterion Setting in Perceptual Decision Making

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Perceptual decision-making involves placing an optimal criterion on the axis of encoded sensory evidence to maximize outcomes for choices. Optimal criterion setting becomes critical particularly when neural representations of sensory inputs are noisy and feedbacks for perceptual choices vary over time in an unpredictable manner. Here we monitored time courses of decision criteria that are adopted by human subjects while abruptly shifting the criterion of stochastic feedback to perceptual choices with certain amounts in an unpredictable direction and at an unpredictable point of time. Subjects viewed a brief (0.3 s), thin (.07 deg) annulus around the fixation and were forced to judge whether the annulus was smaller or larger than an unknown boundary. We estimated moment-to-moment criteria by fitting a cumulative Gaussian function to the data within a sliding window of trials that are locked to a shift in feedback criterion. Unpredictable shifts in feedback criterion successfully induced shifts in actual decision criterion towards an optimal criterion for most of subjects, but with time delay and amount of shifts varying across individual subjects. To find a mechanism that generates these individual differences, we developed a dynamic criterion learning model by modifying a reinforcement learning model, which assumes that a criterion is adjusted every trial by a weighted discrepancy between actual and expected rewards. The model simulation revealed that the balance between sensory encoding precision and criterion adjustment weighting defines optimal and suboptimal regimes of dynamic criterion shifts. Subjects exhibited 'overshoots' – going beyond the optimal criterion – and 'undershoots' – remaining below the optimal criterion – when an adjustment weight is greater and smaller, respectively, than an optimal weight that is determined by a degree of sensory encoding precision.

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23.410 Integration of dynamic reward schedules and speed-accuracy tradeoff in perceptual decision making

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We investigated how humans trade off speed against accuracy in a modified random-dot motion task where the reward for making correct direction judgment decreased over time. To perform well in this task, the subjects needed to choose a response time that appropriately balanced the probability of making correct judgment (an increasing function of time) and the reward schedule (a decreasing function of time). We developed an optimal model of response time based on statistical decision theory. In this model, an ideal decision maker takes into account knowledge of his/her own speed-accuracy tradeoff (SAT) and the decreasing reward schedule to choose a response time so as to maximize expected reward. Method. Subjects were first trained to make direction judgment under 20 different conditions (5 different time constraints x 4 motion coherence levels). The subjects received a small and fixed monetary reward (1 cent) for making a correct judgment within the time limit and a relatively large penalty (5 cents) if s/he did not respond within time limit. This session allowed us to separately estimate SAT for each of the 4 coherence levels. In the following session, for each coherence level, we implemented 3 different decreasing reward schedules. The subjects could freely choose the time s/he preferred to make direction judgment but the amount of reward received if correct depended on the time the subjects made a button press to indicate his/her direction judgment. Results. Four subjects participated in the experiment. Each subject exhibited unique SAT profiles that varied as a function of coherence. All subjects adjusted mean response time when facing different reward schedules. Two subjects' performance was indistinguishable from optimal in their timing, while the other two failed to adjust response time appropriately predicted by the optimal model.

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23.411 The effect of visual salience on multiple-alternative, value-based decisions

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Recent studies have shown that during value-based decisions fixation durations at each alternative are directly related to the alternative's relative value and are predictive of choices. However, these studies have not determined to what extent bottom-up visual saliency affects these fixation durations. One recent study has shown that during two-alternative, value-based decisions, subjects' decisions can be biased towards more salient items at short latencies. It is currently unclear whether this occurs during multiple-alternative decisions and to what extent information about saliency and value are combined. Here, we measure eye movements and decisions from from ten human subjects performing a multiple-alternative, forced-choice task involving snack food items. After fasting, subjects viewed displays containing between four and twenty-eight different snack food items and chose which item they would most like to eat at the session's end. By controlling the display duration, we quantified the temporal dynamics of the influence of saliency and preference on fixation locations and final choices. Our results show three distinct effects of saliency on value-based decisions. First, fixation duration increases with increasing saliency of the item fixated and that this effect is strongest at short display durations. Second, as subjects visually explore the alternatives, the saliency of the items fixated decreases with increasing numbers of fixations while the preference of the items fixated increases. Finally, decisions made at very short latencies are more biased towards more salient items whereas decisions made at long latencies are more biased towards more preferred items. All of these results persist regardless of the number of alternatives. These results show that during multiple-alternative decision-making saliency has a large effect on value-based decisions when subjects are under time pressure, often causing them to pick the most salient item regardless of its value.

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23.412 Pupil dilation reflects the difficulty of evaluations in decisions under risk

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Background: Changes in pupil size can reflect not only illumination but also arousal and other cognitive processses. Studies of decision making have shown pupil dilation related to errors in judging uncertainty, and shifts between task engagement and disengagement, which may be related to phasic noradrenalin activity. Objective: We asked whether pupil dilation also indexes judgments made in decisions under risk, when participants must weigh the knowable value of different prospects to make a choice. Method: 19 subjects had to choose between 2 explicitly described prospects, one having higher probability, the other having larger magnitude of reward. Probability and magnitudes varied so that the difference in the expected values between the two prospects varied between 3% to 23%, with half of trials having larger expected value on the side of the larger reward, and half having greater expected value on the side with greater probability. Subjects were given 4 seconds to make a choice and a video eye tracker recorded pupil sizes during that interval. We analysed pupil dilation, operationalized as the difference between the initial minimum pupil size and the maximum pupil size, and examined its relation to various parameters involving reward magnitude, probability, expected value, and mean variance. Results: Pupils reached maximum size at around 2250ms. Pupil dilation was correlated with the sum of reward magnitude of the two prospects (r=0.52), and there were trends to an inverse relationship with the percent difference in expected value between the two prospects (r= -0.48), and the percent difference in mean variance, which indexes the difference in riskiness (r= - 0.49). Pupil dilation did not vary with probability information. Conclusion: Pupil sizes can reflect both reward size and the degree of difficulty involved in decisions under risk when choosing between prospects.

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23.413 **Groups detect wholes better than parts**

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Signal detection theory typically considers a single observer's response to a given signal. However, signals can also be received by multiple observers simultaneously, allowing for aggregate group-level decisions to be made. Recent experiments have shown that the sensitivity of a group of observers making a group-level decision about the presence of a redundant signal tends to exceed that of any individual observer (Bahrami et al., 2010). In these previous experiments, each observer received an identical copy of the stimulus and the group as a whole made a decision about the signal's presence. Here, we take this approach a step further by asking whether group-level sensitivity is further enhanced by making the signal non-redundant—i.e., by splitting the stimulus up across observers within a group. To test this possibility, 12 groups of 4 subjects were given the task of detecting the presence or absence of a Gaussian bump embedded within Gaussian noise. The stimulus consisted of a square region, with one bump appearing in the center of one of the 4 quadrants of the square. Groups were randomly assigned to one of two conditions: In the 'full' condition, all subjects viewed all four quadrants. In the 'partial' condition, each subject was shown just a single fixed quadrant. Following each stimulus presentation, the group was allowed to engage in free discussion, after which one individual was randomly chosen to be the final 'decider' for the group as a whole. We found that groups in the 'full' condition significantly outperformed groups in the 'partial' condition, indicating that, in the case of signal detection, sharing redundant information produces better performance than dividing information across the members of a group.

Acknowledgement: NIH/NEI R01-EY019265

23.414 **Rapid coding of novelty-induced orienting in the parietal lobe**

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The lateral intraparietal cortex (LIP) is thought to encode a salience map of the external environment that guides visual attention and gaze. There are, however, multiple factors that determine salience including visual properties, task relevance, Pavlovian reward associations and novelty/familiarity. Little is known about the mechanisms that draw attention based on these factors. We previously reported that visual salience is determined in part by Pavlovian associations, such that cues predicting reward attract attention while cues predicting no reward inhibit attention from their location, and these effects are automatic and independent of operant decisions (Peck, Jangraw et al., 2009). Here we extend these findings to examine the correlates of novelty-driven orienting. Two monkeys performed a task where a peripheral cue signaled the reward probability of a trial. To measure whether the cue attracted attention, we required monkeys to hold fixation for 600ms and then make a saccade to a separate target that appeared unpredictably at the same or opposite location as the cue. The cues were distinct colored patterns that could be novel or familiar and signal 100% or 0% probability of reward. Familiar cues had received prolonged training with consistent reward associations, while each novel cue was used for only a single session. Monkeys quickly learned the reward value of novel cues (shown by their anticipatory licking) and testing began after this learning was complete. Novelty produced a multiplicative enhancement of the LIP response, which persisted throughout a session (~30 cue presentations) and interacted linearly with the reward effect. This enhancement appeared within 100ms and was spatially specific, correlating with a rapid attentional capture produced by the novel cues. We suggest that LIP provides a short-latency signal that mediates fast visual orienting toward novel stimuli, which may precede recognition and interpretation of the reward properties of these stimuli.

Acknowledgement: NEI, NARSAD, Gatsby Foundation

23.415 **Reward Prompts Visual Short-Term Memory Consolidation**

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Motivation and reward are known to facilitate the development of our adaptive behavior. Recent literatures have suggested that learning to associate visual feature with reward increases its visual saliency. However, it remains unclear whether reward learning can prompt the consolidation of visual representation and makes the visual feature better accessible in working memory. To establish a reward-color association, our observers were trained on a visual search task. During the training, eight bars inside colored circles were shown for 500 ms at equal eccentricity around the central fixation. The bar with odd orientation was the target and appeared only inside red or green circle. Correct response was associated with high probability (80%) of high monetary reward in one condition (e.g., red circle) and high probability (80%) of low monetary reward in the other condition (e.g., green circle). Before and after the training, we estimated the reward effect on visual short-term memory with a change detection paradigm. Eight bars differed in orientation and color were shown and observers were to determine whether the probed bar had rotated by 90 degree between sample and test displays. The sample display was shown for 500 ms and followed by a blank interval (1000 – 2500 ms) before the test display appeared. Performance improvement in detection sensitivity (d') was calculated. The results show significantly larger improvement in sensitivity if target's color was associated with high reward compared to low reward ($p<0.05$) and no reward ($p<0.05$) during the training, despite the fact that reward-associated feature (i.e., color) was implicitly learned and tested in the absence of task-relevance. No significant effect of reward in shift of decision criterion is found. Our findings demonstrate an important role of reward association in visual short-term memory consolidation. This effect exists even if the association is implicitly learned.

Acknowledgement: National Natural Science Foundation of China (31070896)

23.416 **fMRI evidence for robust perceptual judgements in human observers.**

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Sensory information is noisy and so inferences about the visual world benefit from repeated sampling and integration of evidence into a cumulative 'decision variable' or DV. Computational modelling and single-unit recording studies show that the DV scales with mean signal strength. However, for many psychophysical stimuli (e.g. random dot kinematograms) this quantity is confounded with signal variability, a quantity important for estimating the reliability of visual information. To assess how the DV is computed during visual categorisation, we asked human observers to discriminate multi-element arrays in which the mean and variance of a decision-relevant dimension (shape or colour) were manipulated orthogonally. Observers were slower to respond to more variable arrays, and weighted outliers less heavily in the decision. This replicates recent modelling work, which showed that observers accumulated the total log posterior ratio (LPR) associated with the two alternatives, calculated from the sigmoidal likelihood function linking elements to choices, rather than accumulating mean evidence or signal-to-noise ratio. Here, we additionally used functional magnetic resonance imaging (fMRI) to assess the validity of the LPR model at the neural level. Analysis focused on the ventromedial prefrontal cortex (vmPFC), a brain region where blood-oxygen level dependent (BOLD) signals correlate with the probability of receipt of positive feedback or reward. BOLD in the vmPFC correlated with the mean LPR associated with the array, even when the raw mean and variance of both decision-relevant and decision-irrelevant dimensions were included as nuisance covariates. This suggests that observers do indeed calculate the log posterior ratio during categorical choice. However, we also observed dissociable BOLD correlates of the signal mean and variance in the parietal cortex, suggesting that the statistics of the array are computed there. Together, these data provide neural evidence that humans make categorical judgements in a statistically optimal fashion.

Acknowledgement: Medical Research Council, The Wellcome Trust

Visual memory: Neural mechanisms

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

23.420 Stable Visual Working Memory Representations Across Changes in Eye Position

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We perceive a stable visual world despite changes in eye position that cause objects to shift from one visual field to the other. One theory is that we use visual working memory (VWM) to integrate object information from across fixations. However, given the contralateral organization of VWM in the brain, it's unclear how eye position changes that cause remembered objects to shift across visual fields would affect which hemisphere will continue to maintain the object information. This could occur in two ways. A "shift" account predicts that the objects in VWM would initially be represented in the contralateral hemisphere, but would then shift to the opposite hemisphere following the change in eye position. Alternatively, a "hold" account predicts that the objects would continue to be represented in the initial contralateral hemisphere despite the change in eye position. To test this, we recorded event related potentials while subjects performed a change detection task with 2 or 4 colored squares. Subjects began all trials fixating a central cross prior to the presentation of the memory array. For 50% of trials, subjects maintained central fixation throughout the entire trial. For the other 50% of trials, they were cued to refixate a new position that was 7 degrees to the left or right of central fixation during the middle of the retention period, thus bringing the objects into a new visual field. The results showed a sustained contralateral delay activity (CDA) that persisted in the original contralateral hemisphere even after the subjects had refixated. A subsequent control experiment in which subjects fixated laterally prior to object onset, confirmed that these results were not due to the CDA being spatiotopically organized. Together these results support a "hold" account in which item representations remain stable in the initial encoding hemisphere despite later changes in eye position.

23.421 The Representation of Stimulus Identity for Multiple Items in Short-Term Memory Revealed Using fMRI Classification

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Numerous neuroimaging studies have revealed that sustained activity in the intraparietal sulcus (IPS) and lateral occipital (LO) cortex is present during the delay period of change detection tasks, and increases as a function of memory load, suggesting that these areas play a critical role in visual short-term memory (VSTM) maintenance. In contrast, using multivariate multivoxel pattern analysis (MVPA), other studies have found evidence for stimulus-specific information in early visual cortex, suggesting that these regions also play a critical role in representing information in VSTM. In the present study, we examined this discrepancy between univariate and multivariate techniques by examining the effect of load on the classification of motion direction during a VSTM task. On each trial, subjects were presented with 1, 2 or 3 apertures of moving dots at 100% coherence (the memory sample). After a 9 second delay, a circle with a line indicating the direction of the motion was presented, and participants were told to orient the line to indicate the direction of the sample stimulus presented at that location. For each trial, the target was selected from one of 3 tangential orientations (0˚, 120˚, and 240˚). Data from individual trial time points were used to train separate classifiers to classify each of the 3 directions of motion. A trial is considered correctly classified if the correct direction had the highest likelihood (winner-take-all classification). Results show that classification accuracy is above chance for loads 1 – 3. Overall accuracy, however, as well as target-direction evidence, decreased as a function of load, consistent with the decrease in VSTM performance with increasing set size. The results are compared to behavioral measures of accuracy and resolution.

23.422 The neural correlates of visual working memory decline in normal aging.

Philip Ko[1](philip.c.ko@vanderbilt.edu), Bryant Duda[1], Erin Hussey[1], Emily Mason[1], Geoffrey Woodman[2], Brandon Ally[1,2,3]; [1]Department of Neurology, Vanderbilt University, [2]Department of Psychology, Vanderbilt University, [3]Department of Psychiatry, Vanderbilt University

Visual working memory (VWM) allows for the temporary retention of information and is critical for normal daily functioning. Older adults show lower VWM capacity compared to younger adults (Brockmole et al., 2008), which could significantly impact their performance in common but potentially dangerous contexts such as driving (Rizzo et al., 2009). To better understand the neural underpinnings of the age-related decline in VWM, we examined the electrophysiological index of VWM maintenance in healthy older and younger adults. Specifically, the contralateral delay activity (or CDA) of an observer's event-related potentials (ERPs) provides a measure of what is actively maintained in VWM and predicts that individual's VWM capacity (Vogel & Machizawa, 2004). In the current study, younger (mean age = 22.9 years) and older adults (mean age = 68.2 years) viewed a bilateral visual display and were cued to remember a variable number of colored objects in one hemifield. Both younger and older adults showed a significant CDA in posterior regions, but the CDA of older adults was significantly reduced in amplitude. Despite this electrophysiological effect, there were no statistical differences across groups in the behavioral estimates of VWM capacity. Our electrooculogram recordings showed that this dissociation was due to the older adults using overt selection to aid maintenance of the information in VWM. That is, older adults made more deviant eye movements towards the target hemifield during encoding and well into the maintenance period. The failure of older adults to inhibit eye movements (Wilson et al., VSS 2011) suggests that they utilize overt spatial attention to compensate for loss in the ability to covertly maintain representations in VWM compared to younger adults.

23.423 Spike count correlations in visual, visuomotor, and motor neurons of macaque prefrontal area 8A during working memory maintenance

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We examined spike count correlations between neurons in prefrontal area 8A of two macaca fascicularis during a spatial working memory task by recording the responses of multiple units using microelectrode arrays (Blackrock Inc., UT). The task consisted of fixation on a central spot for 494-800ms, then presentation of a circular sine wave grating at one of 16 randomly selected locations for 507ms. After extinguishing the grating, there was a delay period of 494-2000ms, followed by extinguishing of the central fixation point, which instructed the animals to make a saccade to the remembered stimulus location. We recorded the activity of neurons in blocks of 32 channels and sorted spikes using Plexon software (Plexon Inc, TX). We isolated responses of 191 single units for a total of 1170 neuronal pairs. Neurons were classified as being selective (one-way ANOVA, $p<.05$) for visual stimuli (visual, n = 29, or 15%), saccades (motor, n = 22, or 12%), or both (visuomotor, n = 78, or 41%). We then quantified the proportion of significant positive and negative spike count correlations as well as the proportion predicted by chance (shuffled correlations) in each group. In visual units the proportion of significant positive and negative correlations during the memory period were both significantly greater than expected by chance (positive = .22 and negative = .13, $p<0.05$). In motor and visuomotor units, only the proportion of significant positive correlations was significantly greater than chance (motor = .18, visuomotor = .17, $p<0.05$). Our results show that during working memory maintenance visual, motor, and visuomotor units in area 8A exhibit different degrees of correlated firing. This suggests that these different cell types may play different roles in the network dynamics underlying working memory maintenance by prefrontal neurons.

23.424 Improving visual working memory performance with transcranial direct current stimulation

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Visual working memory (VWM) capacity in humans is reached when individuals show an asymptotic activation level in the posterior parietal cortex, at around 3-4 items. We found that artificially increasing posterior parietal activity via positively-charged noninvasive anodal electric current, known

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as transcranial direct current stimulation (tDCS), can increase people's VWM performance. This artificial improvement is more robust in low-capacity individuals who tend to remember less information. Event-related potential (ERP) comparisons between tDCS and sham conditions revealed that tDCS induced greater amplitudes in N2pc and sustained posterior contralateral negativity (SPCN), components that have been shown to reflect deployment of visual-spatial attention and maintenance of information in VWM, respectively. Together, these results suggest that VWM performance can be efficiently improved with external neural stimulation, which directly impacts the processes of visual attention and memory maintenance.

23.425 Decoding concepts for famous people from BOLD responses in the left anterior temporal lobe

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Where do you know who you know? There are faces that are instantly recognizable and nameable. Conversely, there are names that automatically bring up an associated face. Some neurons are likely to respond to both the name and the face of these familiar individuals – in fact, such neurons with an invariant, explicit and selective response to both famous and familiar individuals, e.g. Jennifer Aniston, are routinely found with the aid of implanted microelectrodes in the medial temporal lobes of human patients (Quian Quiroga, Reddy, Kreiman, Koch, & Fried, 2005). We set out to investigate such modality-independent, conceptual representations with fMRI. We conducted an event-related fMRI study in which subjects were asked to recognize and name three famous actors (Brad Pitt, Matt Damon and Tom Cruise) from various pictures or to read their written name, on separate trials within each run. We used high resolution fMRI (2x2x2mm voxels) with 30 axial slices covering the occipital and temporal lobes. Performing multivariate pattern analysis (linear support vector machine classification, with leave-one-run-out cross validation) within a searchlight volume operating throughout the brain for each subject, we demonstrated at the group level (seven subjects) that activity patterns specific to the name of a given actor allow decoding of their identity upon presentation of their face, and vice-versa. Such patterns were only found in the left anterior temporal lobe, consistent with a large body of lesion and imaging studies implicating this region in the retrieval of proper names (Patterson, Nestor, & Rogers, 2007). This result opens up a new avenue of research which has the potential to address critical issues in the field of semantic memory and concept retrieval in the human brain.

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23.426 Incidental reactivation of visual event features promotes long-term remembering

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Recalling a past visual experience activates cortical structures that were engaged during the initial encoding of that experience. This phenomenon of neural reactivation is thought to underlie our subjective experience of remembering. However, when recalling past experiences, we are often trying to retrieve specific event features, such as information about object categories or their spatial locations. Does recalling one feature of a visual experience elicit incidental neural reactivation of other event features? If so, does such incidental reactivation of non-target event features strengthen memory for these features? We addressed these questions in a human fMRI study (n = 18) using pattern classification analyses to measure neural reactivation of memory features. During fMRI scanning, participants engaged in alternating study-test rounds. In study rounds, words were paired with images of faces or scenes that appeared on the left- or right- hand side of the screen. During test rounds, words were presented and participants were either instructed to recall the location (left/right; 1/3 of study items) or category (face/scene; 1/3 of study items) of the corresponding image; for the remaining 1/3 of study items, neither feature was tested. After scanning, participants completed a post-test that assessed their memory for both features (location and category) for each studied word. Pattern classification analyses revealed robust neural reactivation of feature information during the test rounds, including reactivation of non-target features (e.g., reactivation of face/scene information during location retrieval). Moreover, non-target features were much better remembered at post-test than features of items that were not tested at all, and this memory benefit for non-target features correlated with their incidental reactivation during test rounds. Thus, retrieving one feature of a visual event from memory can elicit incidental neural reactivation of other event features, thereby facilitating future remembering.

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23.427 Assessing the necessity of the medial temporal lobes in visual probability learning

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A number of studies have implicated the medial temporal lobe (MTL) memory system in the ability to extract probabilistic visual relationships (i.e., visual statistical learning), suggesting that such learning may be related to other forms of relational and associative memory. However, these studies have almost exclusively employed neuroimaging methods and as a result the necessity of MTL structures in probabilistic visual learning has yet to be tested. In the current study, two amnesic patients with bilateral damage to the medial temporal lobes participated in two visual probability learning tasks, one requiring the learning of temporal relationships and the other requiring the learning of feature-based relationships. Each patient showed performance equal to normal comparison participants on both tasks, providing evidence that MTL structures are not critically involved in visual learning based on probability. These results suggest the possibility that other memory systems (e.g., basal ganglia, low-level cortical plasticity mechanisms) may be more important in this process.

23.428 Hemispheric differences in visual working memory maintenance indexed by contralateral delay activity

Maro Machizawa[1,2](m.machizawa@ucl.ac.uk), Crystal Goh[1], Jon Driver[1,2,3], Masud Husain[1,2]; [1]UCL Institute of Cognitive Neuroscience, [2]UCL Institute of Neurology, [3]Wellcome Trust Neuroimaging Centre at UCL

Investigations on patients with hemi-neglect or individuals with virtual lesions using transcranial magnetic stimulation (TMS) have suggested there might be hemispheric biases in visual processing, with possible right hemispheric dominance in visual attention and aspects of working memory. EEG studies of visual working memory in humans have until now treated both hemispheres equally, with the majority of the studies collapsing data across left- and right-attended conditions. Here, we examined whether a neural correlate of visual short-term memory maintenance, contralateral delay activity (CDA), reflects any hemispheric differences as a function of attended hemifield. We tested participants on visual working memory tasks. For each trial a brief sample display presented bilaterally either two or four items in each hemifield. One hemifield was made task-relevant by precuing for retention over 1,500ms. Color of samples (either red or green) indicated expected difficulty of probe (fine or coarse). The results revealed significant differences, with left-attend CDA activity maintained over time while right-attend activity decayed over the delay period. In addition, CDA amplitudes across all conditions within one hemifield correlated significantly with each other, while amplitudes between different hemifields did not. This was further confirmed by a principal component analysis on CDA amplitudes in all conditions that extracted two principal components: the first component loaded only with left-attend conditions while the second loaded only with all right-attended conditions. Voxel-based morphometry analysis (VBM) revealed significant associations between regions in posterior parietal and lateral occipital cortex and sustainability of the CDA component. These results suggest there are significant differences in CDA for left and right visual stimuli maintained in visual working memory, suggesting the nature of the CDA signal might be more complex than previously supposed.

Perception and action: Navigation and locomotion

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

23.431 Vection in depth during treadmill locomotion

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Saturday AM

The research on vection during treadmill locomotion appears contradictory. For example, Onimaru (2010) reported that walking forwards on a treadmill impaired the vection induced by expanding flow, whereas Seno et al (2011) appeared to find a vection enhancement in these conditions. These previous studies both examined smooth self-motion displays, despite the fact that jittering displays have consistently been shown to improve vection in seated observers. We simulated constant velocity expanding and contracting optic flow displays, in which subjects physical movements were either updated as additional display jitter (synchronised head-display motion) or not updated into the self-motion display. We also varied the display/treadmill forward speed – these could be simulated at either 4 km/hr or 5 km/hr. Subjects viewed displays in real-time while walking on a treadmill or on the spot and as passive playbacks while stationary. Subjects rated their perceived strength of vection in depth using a joystick (compared to a standard reference stimulus). We found vection impairments for both expanding and contracting optic flow displays and similar impairments when subjects actively walked on the spot. Despite finding a general vection impairment for active walking, faster display/treadmill forward speeds and synchronised head-display jitter improved vection. It was concluded that vection impairments while walking appear to be independent of the display's simulated direction and the nature of one's walking activity.

23.432 **What infants see depends on locomotor posture**

Kari Kretch[1](kari.kretch@nyu.edu), John Franchak[1], Julia Brothers[1], Karen Adolph[1]; [1]Department of Psychology, New York University

Vision is a whole-body process involving eye, head, and body movements, so where people look is constrained by the properties of their bodies. We investigated whether developmental changes in locomotor posture—specifically, the transition from crawling to walking—affect infants' visual experiences. Thirteen-month-old infants crawled or walked down a 490-cm walkway wearing a head-mounted eye-tracker that recorded their eye movements and field of view. The walkway and opposite wall were covered with regularly spaced stripes. Coders scored videos frame-by-frame to determine the highest and lowest stripes visible in the scene camera, approximating the top and bottom of infants' visual fields. Walkers had a better view of distal locations and experienced a richer visual environment filled with people and objects. Walkers could see across the room to the opposite wall 98% of the time, compared to only 78% for crawlers. Thus, for crawlers, the floor completely filled their visual fields 22% of the time. Comparing times when infants could see across the room, walkers could see significantly higher than crawlers (M=138 cm vs. M=66 cm), and were more likely to see their parents and objects in the distance. Conversely, crawlers had a better view of the floor; crawlers could see the floor 99.5% of the time but walkers only 88% of the time. When the floor was in infants' visual fields, the closest visible point was significantly closer for crawlers than walkers (20 cm ahead of crawlers' hands vs. 87 cm ahead of walkers' feet). Therefore, crawlers obtain more visual information about proximal objects and obstacles. Results indicate that what infants see is intimately tied to body constraints and that infants' visual world is transformed with changes in locomotor posture. Ongoing analyses are investigating the effects of the shifting visual field on infants' visual fixations, using gaze calculations from the eye-tracker.

Acknowledgement: NICHD R37-33486

23.433 **Obstacle detection during walking by patients with tunnel vision**

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"Tunnel vision" (severe peripheral visual field loss), a long-term sequela of visual disorders (e.g., retinitis pigmentosa and choroideremia), causes difficulty detecting and avoiding obstacles during locomotion. We examined the obstacle detection behavior of seven patients (visual fields 6˚-27˚ wide) as they walked to a visible goal in a virtual environment with or without an obstacle present. The obstacle was a short (1.2m) or tall (1.8m) stationary pole appearing at a distance of 4 or 6m from the participant and offset from the straight path between patients' starting position and the goal by an angle of 1˚ or 4˚ (short obstacle) or 1˚ (tall obstacle). Obstacle and goal poles appeared after participants traveled 1m, and participants pressed a button when they detected an obstacle. Pearson correlations were computed to examine the relation between each participant's detection rate and their mean trial duration. Significant negative correlations were found between detection rate and trial duration for both the short and tall obstacle ($r = -0.79$ and -0.76 respectively; $p \leq .05$). Closer examination revealed significant negative correlations between detection rate and trial duration for both the short and tall obstacles at 6m with a 1˚ offset ($r = -0.77$ and -0.84, respectively; $p \leq .05$), and a negative trend for the short obstacle at 6m with a 4˚ offset ($r = -0.68$, $p=.09$). No significant relations were found between detection rate and measures of patients' visual fields or visual acuity ($p>.05$). These results suggest that patients had greatest difficulty detecting more distant obstacles, and that participants who took more time to try to detect the obstacle actually had lower detection rates. Testing of age-matched controls is in progress and analysis and modeling of the locomotor trajectories are ongoing to simulate patients' detection and avoidance. The results will help provide a basis for developing interventions for improved mobility.

Acknowledgement: Marc Ernst

23.434 **Avoiding Two Vertical Obstacles: An Age-Related Comparison**

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When individuals must pass through an aperture, young adults (YA) initiate a shoulder rotation at smaller relative aperture widths1 (i.e. Critical Point) than older adults (OA)2,3. It is unknown whether individuals initiate changes to actions at similar relative aperture widths between obstacles in unconfined space as in a confined aperture-crossing. The current study aimed to determine the Critical width at which individuals change action strategies and if age-related differences exist when avoiding obstacles in unconfined space. Young (N=12) and older adults (N=12) were instructed to walk a 9m path toward a goal and avoid two poles placed 5m along the path on either side of the midline (0.6-1.8x shoulder width). Results showed that the Critical width of YA was 1.4x shoulder width while OA was 1.6. In confined and unconfined space the passability of apertures remains similar, however the action strategy differs. Rather than change shoulder position, a change in travel path occurs. When changes in travel path were made, YA deviated from straight walking further from the obstacles than OA (2.68m versus 1.78m, $p<0.001$). At the time-of-crossing, OA displayed a larger lateral clearance than YA (0.70m versus 0.31m, $p<0.001$). This suggest that OA require more time to process information and make appropriate action changes but their subsequent strategies are more cautious. Overall, this study confirms the persistence of age-related differences in action strategies and that Critical width governs the initiation of action changes in unconfined space. However, the strategy used is task-specific. 1.Warren&Whang (1987).Visual guidance of walking through apertures:Body-scaled information for affordances. J.Experimental Psychology,13:371-83. 2.Wilmut&Barnett (2010).Locomotor adjustments when navigating through apertures. Human Movement Science,29:289-98. 3.Hackney&Cinell (2011).Action strategies of older adults when walking through apertures.Gait and Posture,33[4]:733-36.

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23.435 **Assessing Spatial Updating Using Continuous Pointing: Effects of Age and Expertise**

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Self-motion perception refers to the ability to perceive egocentric speed and direction of movement through space and is typically informed by several different sensory systems. Currently, little is understood about how aging and experience affect self-motion perception when walking under reduced sensory conditions. Therefore, this experiment compared the spatial updating performance of healthy younger adults (ages 20-25), healthy older adults (ages 60-72), and high-level, large-area, team sport athletes, under sighted walking, blind-walking, and imagined walking conditions using a previously described continuous pointing task (Campos et al., PLoSOne, 2009). Participants viewed a target positioned in front and to the right of them. Then, with eyes open or closed, they pointed continuously towards the target as they walked past it, or imagined walking past it along a straight, forward path. Pointing behaviour was tracked using an Optotrak motion capture system (NDI, Waterloo, ON), which provided 3D tracking of the head, trunk and pointing hand at 60Hz. It was expected that, if accurate spatial updating occurred, the maximum arm azimuth velocity should be observed upon target passage when the arm azimuth angle was zero

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degrees. Results showed that younger and older adults demonstrated this characteristic pattern of pointing during both sighted and blind-walking (95-98% of maximum arm azimuth velocities occurred at zero deg.), but not during imagined movement; particularly in older adults (80% and 62% for younger and older adults respectively). Interestingly, for athletes, pointing during imagined walking resulted in responses that were much more consistent with responses during actual self-motion (88% of maximum arm azimuth velocities occurred at zero deg). Overall, this study suggests that older adults can spatially update using non-visual inputs during walking, but demonstrate clear failures in motor imagery in the absence of relevant sensory inputs. In contrast, athletes demonstrated a superior ability to perform locomotor mental imagery.

23.436 **The visual control of locomotion during interception and avoidance of moving objects**

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Many locomotor tasks, including intercepting targets, avoiding obstacles, and selecting routes, involve interactions with moving objects. A simple strategy for intercepting moving targets is to move so as to keep the target at a fixed bearing angle. Likewise, moving obstacles can be evaded by moving so as to avoid keeping the obstacle at a fixed bearing angle. However, this model does not explain how direction and speed of locomotion are coordinated during interception, does not account for the physical extent of objects, and does not easily generalize to more complex environments with many moving objects. In this study, we consider an alternative model based on eyeheight-scaled information that specifies the locomotor speed needed to intercept or avoid moving objects. First, we test the prediction that manipulations of self-motion information influence the perceived walking speed needed to intercept a moving target. This follows from the fact that the information about required speed is found in the object-motion component of optic flow, which means that the self-motion component must be factored out. Subjects walked to intercept moving targets in a virtual environment viewed through a head-mounted display. Target speed and trajectory varied across trials. The influence of self-motion information was tested by manipulating subjects' movements relative to the stationary background without affecting their movement relative to the moving target. We found small but statistically significant effects of self-motion information consistent with the prediction that movements were guided by information about required walking speed found in the object-motion component of optic flow. Second, we will show how this information can be used to (1) coordinate the speed and direction of locomotion during interception and obstacle avoidance, (2) avoid obstacles in a way that takes their extent into account, and (3) account for route selection in more complex environments.

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23.437 **Optic flow has an immediate and an enduring effect on the perceived straight ahead in the visual control of steering toward a goal**

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We examined whether the effect of optic flow on locomotion control can be indirect through recalibrating the perceived straight ahead (SA) and thus affecting the perceived target egocentric direction. The display (110°Hx95°V) simulated a participant walking over a textured ground plane at 2 m/s. In each 10-s trial, participants used a joystick to steer toward a target placed 25 m away within 15° from their SA (i.e., their body midline). Their simulated heading in the display was displaced 10° to the left or right of their SA. In Experiment 1, a vertical line was flashed for 100 ms at 0, 2.5, or 5 s after each trial, and 10 participants were asked to judge whether the line was to the left or right of their SA. A 2AFC adaptive procedure was used to find a point of subjective equality (PSE) representing the line position corresponding to the perceived SA. The staircases for left and right heading displacement were interleaved to prevent adaptation. The measured PSE was biased toward the displaced heading by 14%±2% (mean±SE) when the line is flashed immediately after the trial, by 7%±1% at 2.5 s, and the bias disappeared at 5 s. In Experiment 2, 50 participants were asked to use a mouse to move a vertical line to their SA for three times before steering, and 5 s after steering for 20, 30, or 90 trials with left or right heading displacement. The judged SA shifted by 8%±3%, 11%±3%, and 23%±4% of the heading displacement after 20, 30, and 90 trials of steering, respectively, and was mirrored by the change of the last 1-s heading error averaged across the first and the last 10 trials. We conclude that discrepant optic flow causes an immediate and an enduring shift of the perceived SA during locomotion.

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23.438 **Visual control of speed in side-by-side walking**

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Side-by-side walking is a common locomotor interaction in which two mutually visually-coupled pedestrians adopt a common speed and direction of locomotion. Understanding this interaction may help to explain the collective behavior of human crowds. In this study, we tested three behavioral strategies for speed control in side-by-side walking: (1) The Distance Model nulls the distance along the travel axis between a walker and their partner; (2) the Direction Model nulls the angle between the visual direction of the partner and the walker's medial-lateral axis; (3) the Speed Model nulls the difference in speed between the walker and the partner. Two participants were asked to walk next to one another to a goal in an open 12m x 12m room while their head positions were recorded (60 Hz). In the Initial Speed condition, each participant was instructed to begin walking at one of three speeds (slow, normal or fast) and then to walk together to the goal. In the Mid-trial Speed condition, one participant was instructed to change their speed (slow down or speed up) mid trial. The models were fit to the time series of acceleration for each walker, treating the partner's data as input, for all trials in a condition (two free parameters: a coefficient and a time delay). The speed-matching model yielded the highest correlations between simulated and participant data, whereas the distance and direction model correlations were near zero. In addition, participants maintained their initial relative positions along the travel axis throughout a trial, consistent with the speed model. Further tests of models that combine distance and speed are ongoing. Previously, Rio & Warren (VSS 2010) similarly found that a speed model also characterized pedestrian following. Ultimately, components for side-by-side walking and following could be combined to model the emergent behavior of crowds.

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23.439 **On-line steering to occluded goals can be modeled by positional uncertainty**

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When walking a slalom course of five goals, occluding the next one or two upcoming goals significantly disrupts the control of steering (Zhao & Warren, VSS 2011). Specifically, the variable error and undershooting of goal positions increases from the Block 1 to the Block 2 condition. The results are consistent with the view that human locomotion is normally controlled on-line based on current visual information. The steering dynamics model (Fajen & Warren, 2003) can account for these walking trajectories on the basis of visual information about the next 1.5 goals. Here we ask whether the same control mechanism can account for steering to occluded goals, by incorporating positional uncertainty in the spatial memory of goal positions. On each trial, spatial uncertainty was simulated by randomly sampling from a Gaussian distribution of remembered positions centered on the actual goal position, for each goal in a slalom. The sampled goal positions were fed into the steering dynamics model to generate a simulated trajectory for that trial. The SD of the Gaussian distribution was treated as a free parameter. The results indicate that the variable error in human trajectories can be reproduced with a constant positional uncertainty for the Block 1 condition (SD = 0.073m for slalom goals 2-5), and increasing positional uncertainty for the Block 2 condition (SD=0.090m for slalom goal 2, 0.276m for goals 3-5). The pattern of undershooting in the Block 2 condition also implies a bias in the spatial memory for goals 3-5. The results indicate that an on-line steering control model can also account for steering to occluded goals simply by incorporating spatial uncertainty and bias in remembered goal positions.

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23.440 **Speed coordination in pedestrian groups: Linking individual locomotion with crowd behavior**

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Can the collective behavior of human crowds be explained as an emergent property of local pedestrian interactions? More specifically, is it possible that the coordinated movement of crowds emerges from hierarchical chains of leader-follower pairs (Nagy, Akos, Biro, & Vicsek 2010)? To address this issue, we collected data from 5 groups of 4 pedestrians steering toward a common goal. Participants began in a square configuration (0.5, 1.0, 1.5, or 2.5 m sides) and walked in a 12 x 12 m room while their head position and orientation were recorded using an inertial/ultrasonic tracking system (IS-900, 60 Hz). After walking forward for 1 m, they were verbally directed toward one of three goals located 8 m away. Each participant also walked alone at their preferred speed. In a preliminary analysis (Bonneaud, Rio, Chevaillier, & Warren 2010), we showed that participants adjust their individual walking speeds toward a common group speed. Here, we analyze these adjustments based on position in the group. We find that speed adjustments are more pronounced for pedestrians in the back of the group ($R^2 = 0.71$) than in the front ($R^2 = 0.46$). This implies both a side-to-side coupling [because pedestrians in front adjust their speed] as well as a front-to-back coupling [because adjustments are more pronounced in the back]. These results are supported by our data for pairs of pedestrians, which shows that a simple speed-matching model is sufficient to account for following (Rio, Rhea, & Warren VSS 2010) as well as side-by-side walking with a weaker coupling (Page & Warren VSS 2012). We model these local interactions to simulate the speed coordination among participants in the 4-person groups. In this way, by decomposing crowds into hierarchical pairs of pedestrians, we can begin to link individual locomotion with collective behavior.

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23.441 **Does optic flow calibrate foot placement when stepping on a target?**

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Changes that affect a person's body or the environment may produce differences between intended and actual movements. When such changes take place, visuo-motor adaptation allows people to compensate for such errors. Previous research has shown that optic flow is sufficient to drive adaptation to changes in the speed and direction of locomotion, and that adaptation transfers to several functionally similar tasks. In this study, we ask whether optic flow is also sufficient to calibrate precise foot placement when stepping on targets on the ground. The experiment was conducted in an immersive virtual environment (VE) viewed through a head-mounted display. The position and orientation of the head and the feet were tracked by motion capture equipment. Subjects began each trial by standing at a designated home location. When they pressed a button on a handheld remote mouse, a small, rectangular foot target appeared within one step-length of the home location. Subjects were instructed to step on the target and continue walking to a goal post several meters ahead. The entire VE disappeared as soon as subjects began moving such that visual feedback was eliminated while stepping on the target. The VE then reappeared shortly after subjects completed their first step such that optic flow was available while subjects walked to the goal post. Subjects completed three blocks of trials -- an adaptation block during which we manipulated the speed with which subjects moved through the VE (visual gain), and a pre- and post-test during which visual gain was normal. Analyses focused on the effects of the visual gain manipulation on the accuracy of stepping to the ground target as well as the rate and magnitude of recalibration.

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23.442 **Discovering Optical Control Strategies: A Data-Mining Approach**

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A major focus of research into visually guided action (VGA) is the identification of control strategies that map optical information to actions. The traditional approach to this research has been to test the behavioral predictions of a few hypothesized strategies against subject behavior in environments in which various manipulations of available information have been made. While important and compelling results have been achieved with these methods, they are potentially limited by small sets of hypotheses and the methods used to test them. In this study, we introduce a novel application of powerful data-mining and machine-learning techniques in an "assumption-lite" analysis of experimental data that is able to both describe and model human behavior. This method permits the rapid testing of a wide range of possible control strategies using arbitrarily complex combinations of optical variables. Through the use of decision-tree techniques, subject data can be transformed into an easily interpretable, algorithmic form. This output can then be immediately incorporated into a working model of subject behavior. We tested the effectiveness of this method in identifying the optical information and control strategies used by human subjects in a collision-avoidance task. Our analytical results comport with existing research into collision-avoidance control strategies while also providing additional insight not possible with traditional methods. Further, the modeling component of our method produces behavior that closely resembles that of the subjects upon whose data the models were based. Taken together, the findings demonstrate that data-mining and machine-learning techniques provide powerful new tools for analyzing human data and building models that can be applied to a wide range of perception-action tasks.

23.443 **Self-motivated visual exploration of the environment predicts subsequent navigational performance and style.**

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As we learn a navigational route through an unfamiliar environment, we may attend to different aspects of the route in order to remember it later. Some people may focus on the specific sequence of turns involved (an egocentric method), while others may encode distal landmarks and stores, as well as the relative location of the target in relation to these items (an allocentric method). Our participants navigated through an unfamiliar city to a stable target location using a desktop virtual environment with several distal landmarks but no local cues. After varying the starting point and asking participants to mark the location of the target, we compared the participants' navigational path to the egocentric sequence of turns learned through training and the actual target location (which would not be reached from a different start point via the learned sequence). We found that most participants adhered to either a strict egocentric method of following the turn sequence or an allocentric method of identifying the distal landmarks and going to the correct location through a different path. In addition, participants had the option of using a "view mode", which allowed them to raise, lower, and rotate the camera at each intersection. Participants who spent more time in view mode were more accurate in identifying the target location compared to participants who did not use view mode, even when placed at different starting points from initial training. Finally, participants who used view mode were also more likely to adopt an allocentric navigational style, suggesting that these participants were aware of the need to encode distal visual cues in order to accurately find the target location later. By allowing participants to control their view of the environment, we were able to more closely link navigational performance to the encoding of distal visual information.

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23.444 **One thing at a time: Sequential coordination in visual guidance of locomotion-to-reach**

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The information and means of control that allow humans to locomote (Fajen & Warren, 2004) or reach (Anderson & Bingham, 2010) is well-studied, but less is known about the coordination of these actions when locomoting-to-reach. Anderson & Bingham (2010) proposed a new informational variable, hand-centric relative disparity tau, based on the evolution of relative binocular disparities of the hand and target over time. They also proposed a new control strategy, proportional rate control, that maintains informational variables in constant proportion with their own rates of change. In Anderson & Bingham (2011), participants locomoted to targets with outstretched hands and were found to use proportional rate control with head-centric tau to guide movement. Once hand-centric tau specified a time-to-contact less than that of the head-centric tau, participants applied proportional rate control to this now more conservative variable. In the current study, ten participants locomoted to a point-light target to place a point-light on their thumb beside the target. Participants performed 30 trials in each of two conditions: locomoting with an outstretched hand and initiating a reach to the target while locomoting. Results of the former condition replicated Anderson & Bingham (2011). In the latter condition, we hypothesized that head-centric tau would be used to initiate a "ballistic" reach, at the end of

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which head and arm/hand would form a rigid body, control then being switched from head-centric to hand-centric tau to bring the hand to the target using proportional rate control. Reach initiation was best predicted by head-centric tau, with an overall mean value of 0.92, and individual subjects were reliable, exhibiting an average standard deviation of 0.13. Overall, reaches had a mean duration of 530ms and terminated with 678ms actual time-to-contact. Upon termination, the hand was guided to the target using proportional rate control of disparity tau, as shown by regression analysis and model fits.

23.445 **The Role of Perceptual Features vs. Learned Associations in Utilizing Directional Indicators**

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Previous research by Attneave, Palmer and others has examined what kinds of contexts bias stimuli such as triangles to point in one direction or another. However, little research has been done on what perceptual properties make a stimulus indicate direction at all. Shapes such as arrows and triangles are generally used to indicate direction, but it is unclear why they are more commonly used than other similar stimuli such as checkmarks, Ts, or Ys. It is therefore possible that arrows and triangles possess certain perceptual features that make them good at indicating direction. Alternatively, it is possible that stimuli point simply by virtue of a learned association between a shape and a direction. The current line of research seeks to define any features that are necessary and sufficient for any stimulus to indicate direction. To this end, we have modified arrows in an attempt to vary such perceptual features as angle of the chevron on the arrow, ratio of the size of the chevron relative to the length of the line, and thickness of the line, among others. We present a series of experiments that combine subjective ratings (subjects were asked to indicate which direction they perceive a stimulus to point in) and performance measures (navigation, priming, and speeded classification tasks). Interestingly, we found a disconnect between subjects' ratings of pointing direction and their performance on tasks that use those stimuli for navigation (i.e., subjects say a stimulus points East, but they are as fast or sometimes faster utilizing it for moving West). However, pointers do seem to be perceived as indicators of direction (as opposed to symbolic stand-ins for direction), as shown by priming effects, as well as by an interaction between Simon interference and congruency with perceived pointing direction.

23.446 **Horizontal fixation point oscillation and simulated viewpoint oscillation both increase vection in depth**

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Previous research has shown that vection can be enhanced by adding horizontal simulated viewpoint oscillation to radial flow. Adding a horizontally oscillating fixation target to purely radial flow induces a superficially similar illusion of self-motion, where the observer's perceived heading oscillates left and right as their eyes pursue the moving target. This study compared the vection induced by these two conditions for the first time. 15 s optic flow displays (47° wide by 37° high) simulated constant velocity forward self-motion either with/without horizontal simulated viewpoint oscillation (±6.8 deg; 0.58 – 1 Hz). Stationary subjects viewed these displays while fixating a target that either oscillated sinusoidally from the left to the right (±6.8 deg; 0.58 – 1 Hz) or remained fixed at the centre of the screen. We found that fixation point oscillation and simulated viewpoint oscillation both improved the vection induced by radial flow (i.e. stronger ratings, shorter onsets and longer durations of vection relative to no oscillation control displays). Neither vection advantage could be explained in terms of differences in perceived scene rigidity or motion adaptation (based on the subjects' subjective ratings and motion aftereffect durations). Thus, we conclude that both oscillation based vection advantages were generated by the increased global retinal motion and retinal slip.

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23.447 **Step Perception in Older Adults: The Effect of Support on Perceived Height**

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According to the action-specific perception account, a person's action ability influences perception of the environment. Hills appear steeper to people wearing a heavy backpack, are fatigued, or are elderly. In the current experiment we examined the effect of support on perceived step height in older adults. Older adults were asked to estimate the height of a step, either with or without a railing present for support. As people age, they naturally lose their sense of balance, muscle mass, and mobility. As a result, the presence of a railing has an important functional purpose for an older individual. We found that older adults perceived steps to be lower when a railing was present versus when there was no support available. We also found that in younger adults, there was no difference in perceived step height between the two conditions. Furthermore, when older adults were asked to estimate the height of a block used for sitting, the presence of a railing in this case did not affect perceived height. Evidently, the presence of a railing only influences perception in older adults when the support can facilitate performance of an action and when it has some functional purpose. These results suggest that in older adults, perception is sensitive to support that can influence ability or ease with which one can perform an action.

23.448 **Does Path Integration Serve as a "Reference System" for Detecting Landmark Instability?**

Mintao Zhao[1](mintao_zhao@brown.edu), William Warren[1]; [1]Cognitive, Linguistic, & Psychological Sciences, Brown University

Humans and other animals use stable visual landmarks to correct or reset their imprecise path integration system during navigation. But this presents a paradox: how does a navigator determine whether landmarks are spatially stable? We tested two hypotheses in the present study: (1) The reference system hypothesis (Cheng, et al., 2007) proposes that path integration serves as a reference system to detect instability in landmark position. (2) The cue consistency hypothesis (Jacobs, 2002) proposes that landmarks that are inconsistent with ≥2 other spatial cues are detected as unstable. Participants performed a triangle completion task while walking in an ambulatory virtual environment. Local landmarks (towers meters away from home) and/or global landmarks (distant mountains) were covertly shifted prior to the home-bound leg. Landmark instability was manipulated by randomly sampling shift angles from a Gaussian distribution with an SD of 1, 2, or 3 times the SD of path integration; a landmark shift greater than JND (= 2.5 SDPI) should be detectable. Participants completely followed landmarks (both local and global) in the low and medium instability conditions, well beyond the JND, but did so only partially in the high instability condition. When local landmarks were consistent with path integration, participants ignored the shifted global landmarks; however, when global landmarks were consistent with path integration, the shifted local landmarks still influenced the homebound path. These results suggest that (1) path integration serves as a very low-precision reference system that only detects highly unstable landmarks; and (2) consistency of landmarks with path integration helps detect instability, but local landmarks have a greater influence on navigation than global landmarks.

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23.449 **The influence of cast shadows on learning a non-Euclidean virtual hedge maze environment.**

Jonathan Ericson[1](jonathan_ericson@brown.edu), William H. Warren[1]; [1]Brown University

Previously, we created a non-Euclidean hedge maze that contained two "wormholes," which teleported walking participants between locations by covertly rotating the virtual maze. Participants were unaware of this radical violation of Euclidean structure and took shortcuts to the new wormhole locations of target objects, indicating "rips" and "folds" in spatial knowledge. To test whether additional orientation cues would reveal the maze rotation and preserved Euclidean structure, we subsequently added external landmarks. However, shortcut performance was unaffected. In the present experiment, we provide further orientation cues by adding directional cast shadows in the maze. Participants learned the locations of nine objects (places) while freely exploring the maze in three conditions: (1) no external landmarks or cast shadows, (2) external landmarks and cast shadows rotate with the maze, and (3) external landmarks and cast shadows remain fixed with respect to the laboratory. We then probed their spatial knowledge using a shortcut task. Despite the addition of cast shadows to the landmark cues, on probe trials participants still take shortcuts in the direction of wormhole targets rather than Euclidean target locations, con-

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sistent with our previous results. Spatial knowledge is consistent with a topological graph of the environment, supplemented with some coarse metric information, but does not appear to be integrated into a globally consistent Euclidean map.

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23.450 **Mobile Robot Vision Navigation Based on Road Segmentation and Boundary Extraction Algorithms**

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In order to safely navigate in an unknown environment, one has to be able to recognize and traverse the road. We present a monocular vision-based road recognition system that utilizes two opposing vision approaches based on region appearance similarity as well as road boundary detection. Our algorithm works in a general road setting and requires no training or camera calibration to maximize its adaptability to any environment. The appearance similarity approach segments the image into multiple regions and selects the road area by comparing each region's appearance with prior knowledge of the current road, extracted from previous frames (Chang et al., VSS 2011). On the other hand, the road boundary detector estimates the road structure by using the vanishing point in the image. To find the vanishing point, we first compute dyadic gabor pyramids to generate edge maps, which are then used to vote for the most likely vanishing point. From there, we extend a set of rays, spaced every five degrees, and we choose the one most consistent with the underlying edge map orientation. In addition, we also take into account the color difference between the two sides of the rays, which would indicate a likely road boundary. We repeat the process to obtain the other side of the road. We then fuse both region appearance and road boundary information using a Kalman filter to obtain a robust road estimation. We then use it for robot vision navigation by aligning the estimated road center with the robot center. We test the vision navigation system at four sites (one indoor and three outdoor environments) using our mobile robot, Beobot 2.0. The system is able to navigate the robot through entire route for a total 606.69m.

Acknowledgement: NSF, General Motors, ARO and DARPA

23.451 **Visual Search and Spatial Learning in Teleoperation**

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With the development of robotic technology, many tasks that used to be difficult, dangerous, or inaccessible for humans to perform can now be accomplished by specifically designed robots. However, most of the robots that are fully autonomous are not capable of completing a mission all by itself. Therefore, humans are often involved in remotely operating robots from a distance and guide them to accomplish these missions. Remote operation (or a teleoperation) generally involves multiple tasks such as visual search, robot navigation, spatial learning, and so on. However, it is still not well understood how well the human-robot team performs under different conditions, including which tasks should be assigned to the robots and which to the human operator. The present study examined the effect of active control of the robot on visual search and spatial learning in a teleoperation task. A robot was placed in a rectangular maze partitioned by walls to search for color and letter targets amongst distractors. A pair of observers watched simultaneously the online video of the scene taken by a camera mounted on the robot and pressed a key as soon as a target appeared. One of the observers was randomly assigned to command the movement of the robot (active driver), while the other was simply viewing (passive viewer). Both observers drew maps indicating the location of the targets after each exploration trial. Contrary to past research on active control, results showed an advantage for passive operators when participants had access to a map during exploration. However, when the map was removed during teleoperation, performance did not differ between the active and passive operators. These results suggest that fully automated robot navigation is beneficial only when maps of the to-be-explored space are available.

23.452 **EFFECTIVENESS OF 2D CAMERA SYSTEM IN ASSISTING OPERATORS IN VISUAL TASKS**

Frederick Tey[1](tliankhe@dso.org.sg), Mellisa Tan[1], Tong Lee[1], Adeline Yang[1]; [1]Combat Protection & Performance Programme, DMERI, DSO National Laboratories

In aerial refueling operations, boom operators of KC-135 Stratotankers rely on direct vision to command receiver pilots into position and maneuver the flying into the receptacle of receiver aircrafts. A laboratory-based feasibility study was conducted to determine if indirect 2D camera-assisted vision system can be used to replace current unaided vision mode of operation in prolonged awkward postures leading to neck pain, fatigue and discomfort. 8 volunteers who underwent functional vision tests (visual acuities under different test illuminations, contrast sensitivity and colour vision) were recruited to assess suitability of participants and ascertain best corrected visual performance of these individuals using different visual devices (Camera A: wide field-of-view camera with compromised resolution versus Camera B: limited field-of-view camera with superior visual resolution) displayed through a 7-inch LCD display panel. In a simulated task experiment, participants had to remotely control a moving object, "the boom" into a stationary target, "the receptacle" using the proposed visual devices, to determine the feasibility of their applications at the outset of operational missions. In addition, a subjective survey was administered at the end of the experiment to determine the participants' level of confidence in using the camera systems. Successful simulated task outcomes were demonstrated for both unaided and aided vision using Camera B with proposed display. This was supported by favourable participants' confidence: 95%CI (83.41, 97.59), mean=90.5 for unaided vision; 95%CI (11.07, 37.68), mean=24.38 for aided vision using Camera A with display; 95%CI (67.92, 93.08), mean=80.5 for Camera B with display. None of the participants demonstrated successful task outcomes using Camera A with the similar LCD display. More results will be presented during poster presentation. By adopting an ergonomically more compatible 2D camera system (Camera B with LCD display), the boom operators will be able to perform aerial refueling operations remotely in a more comfortable setting.

Acknowledgement: DSO National Laboratories

23.453 **Contributions of attention and decision-making to spatial learning**

Elizabeth Chrastil[1](elizabeth_chrastil@brown.edu), William Warren[1]; [1]Brown University Cognitive, Linguistic, & Psychological Sciences

"Active" navigation seems to yield better spatial knowledge than "passive" navigation, but there could be multiple components of active learning. We have previously examined the contribution of idiothetic information to metric survey knowledge. Here we test additional contributions of two cognitive factors to route or "graph" knowledge: (1) decision-making about one's route, and (2) attention to relevant spatial properties. Participants learned the locations of 8 objects in an ambulatory virtual maze environment, and were tested on their graph knowledge. In Experiment 1, we manipulated decision-making during exploration in two conditions: (a) Free Walking: participants freely explored the environment for 10 minutes, providing all active components. (b) Guided Walking: participants were guided along the same paths, removing decision-making. Spatial knowledge was tested with a Graph task: participants walked from object A to object B within the maze corridors, with occasional detours. Participants in the Free Walking group reached the correct target location significantly more often than those in the Guided Walking group. In Experiment 2, we manipulated attention to spatial properties during exploration by using an orienting task. (a) Graph orienting task: One group was informed they would be tested on their knowledge of the maze layout, and performed practice trials in which they walked through the maze hallways to a target object. (b) Survey orienting task: Another group was informed they would be tested on their knowledge of object locations in space, and performed practice trials in which they turned to face the remembered location of a target object. Both groups were subsequently tested on the Graph task. Preliminary results suggest that performance improves when attention is directed to relevant spatial properties during learning. Together, these two experiments suggest that making decisions during exploration and allocating attention to environmental properties both contribute to active spatial learning.

Acknowledgement: Supported by NSF BCS-0843940

Binocular vision: Rivalry I

Saturday, May 12, 8:15 - 12:15 pm
Poster Session, Vista Ballroom

23.501 Testing the Nature of the Representation for Binocular Rivalry

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Recently, several studies proposed a probabilistic framework for explaining the phenomenon of binocular rivalry, as an alternative to the classic bottom-up or eye-dominant interpretation of it. According to this framework, perception is generated from the observer's internal model of the visual world, based on sampling-based probabilistic representations and computations in the cortex. To test the validity of this proposal, we trained participants with repeated four patterns of two-Gabor patches corresponding to the four possible perceptions in binocular rivalry settings, with a particular probability distribution of appearance (10%, 40%, 15% and 35%). We also tested participants' prior and posterior distributions of these four perceptions in both binocular rivalry and non-rivalry situations, where they either made judgments by what was perceived in rivalry or guessed what could possibly be the answers of Gabor orientation pairs when they saw only non-rivalry Gaussian noise. Kullback–Leibler divergence and resampling methods were used to compare the pretest and posttest distributions from each individual participant. For the non-rivalry inference, three out of four participants showed significant difference ($ps<0.05$) between pre and post distributions of the four possible answers. Compared with the pretest, the post-test distribution shifted towards the target distribution manipulated in the training session. In contrast, for binocular rivalry, none of the participants showed change in the distributions of four perceptions overall from pretest to posttest, suggesting no learning effect transferred from non-rivalry training. Further analysis on the relationship between perception duration time and distribution changes in rivalry showed that with longer perception duration it was more likely to find pre-test and post-test distribution differences. However, the transition from pretest to posttest did not necessarily follow the target distribution from training. These results provided no decisive evidence that binocular rivalry is a visual process based on probabilistic representation.

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23.502 What next? Binocular rivalry is biased by motion direction but not motion pattern

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Dichoptically presented orthogonal gratings compete for perceptual dominance causing the perception of alternating orientations, with each dominating approximately equally often (binocular rivalry). We explored whether binocular rivalry can be biased by preceding the rivalrous display with a predictive context. Observers saw sequences of gratings (presented to both eyes) that either rotated back and forth between two orientations (smooth motion) or rotated from one orientation to another before abruptly returning to the original orientation and continuing in the original direction (pattern motion). Rivalrous displays were presented at the point in the sequence at which the two conditions differed. That is when the grating would either begin to reverse direction (smooth motion) or would return to the original orientation (pattern motion). The rivalrous displays consisted of orthogonal gratings, one that was the next step of the smooth-motion sequence and one that was the next step in the pattern-motion sequence. Observers continuously reported which of the two gratings they perceived. In a control condition in which no sequence of gratings preceded the rivalrous display, the two orientations dominated equally often. In contrast, when there was a biasing sequence, the orientation that was consistent with the next step predicted by the smooth-motion sequence dominated. Critically, this was true regardless of which biasing sequence preceded the rivalrous display. We are exploring whether this bias is attributable to an influence of motion signals on binocular rivalry or an influence of the proximity of recent stimuli. In either case, the results indicate that binocular rivalry was biased by lower-order information (i.e., next step of motion or proximity) but not by higher-order pattern information in the sequence.

23.503 Neural correlates of adaptation within an episode of binocular-rivalry suppression

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Binocular rivalry occurs when an observer looks at two different monocular images. One of the images is alternately suppressed, invisible, while the other is dominant, visible. Models of binocular rivalry hold adaptation responsible for these changes in visual consciousness. Alais et al. (2010, Current Biology) showed psychophysically that depth of rivalry suppression declines within an episode of suppression, consistent with the effects of adaptation. Our aim was to find a neural marker for this decline in suppression depth. We used electroencephalography (EEG) to search for this neural marker. We induced binocular rivalry with dichoptically orthogonal sine-wave gratings. Participants pressed keys to record their perception of orientation. On each trial, we changed one of the gratings to be the same as the other, either to the currently suppressed or to the currently dominant stimulus. On different trials, we made the change at an individually adjusted short time (about 200 ms), medium time (about 700 ms), or long time (about 1200 ms) after the participant signalled a new percept. We found the earliest neural correlate of suppression about 100 ms after the stimulus change, with invisible changes yielding a smaller positive deflection (P1) than visible changes. The P1 difference was pronounced for the short and medium times, and almost abolished for the long time. The decline from short and medium times to the long time is consistent with the expected reduction in suppression depth with time in the suppression interval, and consistent with the psychophysical results. We conclude that we have shown a neural correlate of the adaptation leading to changes in visibility during binocular rivalry.

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23.504 Complementary spatial interactions between binocular rivalry and stimulus rivalry

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When different types of rival visual stimuli – monocular, binocular, and stimulus rivalry – are juxtaposed in neighboring visual regions, perceptual dominance can become entrained among those neighboring regions, implying cooperativity among types of rivalry (Pearson & Clifford (2005) Psychol. Sci.; Andrews & Purves (1997) PNAS). What promotes spatial grouping across those heterogeneous bistable percepts? In particular, is there an asymmetry between different types of rivalry in governing the group dynamics of perceptual reversals? Alternatively, does the grouping presumably result from mutual interaction between the different rivalry types? To answer these questions, we monitored the time course of synchronized perception between binocular (BR) and stimulus rivalry (SR) after triggering a transient perceptual change (Expt. 1) or creating a static imbalance between rival percepts (Expt. 2) in one of the two rivalry types. In Expt. 1, when observers were experiencing coherent perception from juxtaposed BR and SR segments, a brief contrast increment (a "trigger") was introduced in one segment. When presented within the BR segment, the trigger readily induced perceptual state transitions not only in the BR segment but also in the SR segment; a trigger introduced within the SR segment, however, rarely induced a state transition anywhere including its own segment. We obtained a complementary pattern of results in Expt. 2, where a perceptual imbalance was created by a sustained contrast difference between rival stimuli in one segment: the contrast disparity biased the rivalry dynamics of the compound stimulus only when that disparity appeared within the SR segment. This double dissociation implies that BR and SR affect each other's fate via different mechanisms, the former by transient-signal gain and the latter by sustained-signal gain.

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23.505 **Monocularaly unpaired regions do not resist suppression in absence of an explicit occluder.**

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Nearer objects and surfaces occlude further ones differently in the two eyes, resulting in regions on the distant surface visible to one eye but not the other, called monocular occlusion zones. Shimojo and Nakayama (1990) showed that geometrically valid monocular occlusion zones resist rivalry. We used phantom stereograms (Gillam& Nakayama, 1999), to investigate how binocular rivalry might manifest in monocular occlusion zones in the absence of an explicit surface. Participants reported the frequency and duration of monocular feature suppression and perceived depth for three variations of a phantom stereogram. Of these variations only one fully satisfied the geometric relationships consistent with a nearer occluding surface. When a stimulus is geometrically consistent with occlusion, a greater frequency and duration of depth, and a lower frequency and duration of suppression, should be reported, compared to an arrangement inconsistent with occlusion. Results showed significant differences in frequency and duration of perceived depth as a function of geometric consistency. However, geometric consistency did not influence overall rivalry. Further analysis revealed differences in how rivalry manifested as a function of stimulus validity. We conclude that while geometric validity did not eliminate binocular rivalry in these stimuli, it did alter the features that were suppressed.

23.506 **Binocular rivalry between spiral stimuli and linear motion in human observers.**

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Binocular rivalry describes the alternating perception of two competing monocular images. It is hypothesized to arise at multiple levels of the visual pathway due to competitions between neuronal populations that represent the displayed images (Freeman, 2005; Wilson, 2003). From our previous findings, we concluded that the stronger represented expanding motion in area MSTd caused a bias for expansion when presented against contraction (Wilcoxon Signed-Rank test, Left Eye (LE):p=0.0156; Right Eye (RE): p=0.0781) and rotation stimuli (LE:p=0.02345; RE:p=0.02345). Moreover periods were significantly longer for competing spiral stimuli than for our control—rivaling linear motions in the cardinal directions (LE:p=0.0000376, RE:p=0.00000423), even though the latter are more strongly represented in MT and MSTd (Tanaka et al, 1986). We conducted two additional experiments on twelve human observers. The first measured the rivalry periods for combinations of expanding, contracting, or rotating random dot patterns (RDPs) against linear motion RDPs. The RDPs were matched for contrast and speed and were displayed through a mirror stereoscope. We found that a) the bias for expansion ceased and the dominance durations among spiral stimuli were no longer significantly different (LE & RE:p>0.1) and b) spiral stimuli continued to have significantly greater rivalry periods than linear motion stimuli (LE:p=0.000142; RE:p=0.00000553), however the linear stimuli were perceived for longer periods than in our initial experiment (p=0.0078). In the second experiment we compared the rivalry periods for combinations of expanding and contracting RDPs with and without the gradient. In general, stimuli with speed gradients dominated over those without. Moreover, the bias for expansion over contraction was maintained (LE:p=0.0095; RE:p=0.00805). Our results support that motion binocular rivalry takes place at various levels of the visual pathway and it is influenced foremost by the types of stimuli rivaling and by the bias in neuronal representations of those stimuli.

23.507 **Spatial-frequency selectivity of interocular suppression caused by dynamic stimuli**

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By presenting a high-contrast spatial pattern to one eye, a stable interocular suppression can be produced even if the pattern is stationary. This phenomenon has been named "permanent suppression" (PS) (Mauk et al., 1984). Previous studies reported that the strength of the suppression is maximal when a test probe has the same spatial frequency as the suppressing stimulus. Another type of stable and strong interocular suppression, continuous flash suppression (CFS) (Tsuchiya & Koch, 2005), is now well-known, which is generally produced by presenting a series of different Mondrian patterns to one eye at a rate of about 10 Hz. In contrast to PS studies, a recent study (Yang & Blake, VSS2010) showed that interocular suppression due to CFS is mainly observed over a low spatial-frequency range. To investigate whether dynamic switching of suppressing patterns changes spatial-frequency dependence of interocular suppression, the present study examined an interocular suppression caused by a counterphase flickering grating. The suppressing stimulus was a sinewave grating of 7° and flickered at 10 Hz. Its spatial frequency was varied from 0.5 to 8.5 cpd. The test probe was a Gabor patch (σ=0.6°) of various spatial frequencies and presented to the contralateral eye to the suppressing grating. The results clearly showed frequency-selective suppression; when the spatial frequency of the test probe was the same as that of the suppressing grating, an increase in detection threshold of the probe was the largest. Orientation selectivity of suppression was also observed. In additional experiments using filtered Mondrian patterns, we confirmed that low contrast suppressing stimuli produce similar effects to those previously reported. Overall, these results suggest that interocular suppression caused by dynamic stimuli exhibits spatial-frequency selectivity but the suppression also depends on the contrast of the suppressing stimulus. Low spatial-frequency components seem to produce suppression at lower contrast than high frequency components.

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23.508 **Binocular Rivalry with Peripheral Prisms for Treatment of Hemianopia**

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A visual aid for individuals suffering from hemifield loss due to stroke or brain injury uses high power prism segments to shift a region of the blind field into the seeing field's periphery, making it possible for a patient to detect obstacles that otherwise would go unseen. The prisms are usually applied monocularly, which introduces binocular conflict. Since the prism slightly degrades the shifted image, the prism-image could be disproportionately suppressed, and its utility reduced. This has not been found to be the case using abruptly presented probe targets, but real-world obstacles rarely appear abruptly. Here we evaluate binocular rivalry through the prism aid, using stimuli that more closely represent some of the spatiotemporal properties of real-world scenes. Normally-sighted subjects centrally fixated a display through a pair of spectacles to which binocular occluders had been affixed to occlude one side of the visual field in both eyes. On one lens, a 20° Fresnel prism was affixed, shifting content from the occluded field into the seeing field periphery. Corresponding peripheral retinal positions were located so that one eye viewed a target normally while the other eye viewed a target through the prism. Targets were opponent-colored 5° patches of texture (1/f noise or bicolor edge textures) drifting away from the display center, surrounded either by in-phase monochromatic texture filling the ipsilateral display or by a blank field. Subjects tracked the binocular rivalry induced by continually indicating which color (or mixture) was seen during a 30 second recording period. We found that for isolated (no-surround) targets, prism-image predominance could be as low as 10-15%. However, when contrast structure surrounded the targets, prism-image predominance increased, under some conditions achieving parity (40-45%) with the normally-viewed image. We conclude that moving, densely-textured imagery is not roundly suppressed despite the degradation caused by the Fresnel prism.

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23.509 **Discriminating the eye-specific layers of the human lateral geniculate nucleus using high-resolution fMRI**

Larissa McKetton[1](mcketton@yorku.ca), Keith A. Schneider[1,2]; [1]Department of Biology, York University, [2]Centre for Vision Research, York University

Introduction The lateral geniculate nucleus (LGN) is a small thalamic nucleus receiving binocular input from the contralateral visual field. The LGN is organized into six interleaved monocular layers. The dorsal four main layers receive parvocellular (P) input and the dorsal two layers magnocellular (M). Our experimental objective was to directly image and discriminate these eye-specific layers of the LGN in human participants. Methods Participants were scanned using a Siemens Trio 3T MRI scanner and 32-channel head coil. Anatomical regions of interest (ROIs) were

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created for the LGN by manually tracing 1 h of registered and averaged proton density weighted images. Functional MRI scanning utilized an EPI sequence with a 256 matrix and 192 mm field of view, resulting in an in-plane resolution of 0.75 × 0.75 mm2. Stimuli were presented using an Avotec 7021 goggle system that allowed independent high-contrast stimulation of each eye. The stimuli consisted of a field of moving dots, a variable fraction of which moved coherently. The dots in the left and right visual fields periodically switched between the eyes. Subjects were required to detect changes in the direction of coherence. The coherence fraction was manipulated such that subjects were approximately 75% correct, maintaining the attentional demands of the stimulus. Results We were able to reliably activate the LGN using the high-resolution EPI sequence, and we compared these activations to the anatomically defined ROIs as well as to previous results acquired at lower resolutions. Using the high-resolution imaging, we were able to reliably assign voxels as being dominated by one eye or the other and discriminate the monocular layers. Conclusions We have demonstrated that it is possible to discriminate the eye-specific layers of the LGN by directly imaging their functional activation using high-resolution fMRI.

23.510 **Comparison of Binocular Rivalry and Stimulus Rivalry with Manipulation of Interocular Grouping**

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Binocular rivalry results in perceptual alternations with conflicting images in each eye. Stimulus rivalry allows a similar percept despite repeated swapping of the images in each eye (Logothetis et al, 1996, Blake, 2001). Recent studies have further characterized the parameters required for rivalry, and proposed an integrated framework that may suggest a similar mechanism for both types of rivalry (Van Boxtel et al, 2008). However, a direct comparison of binocular and stimulus rivalry has not been reported with manipulation of interocular grouping. We tested subjects with matched stimuli in both rivalry conditions. The stimuli were sinusoidal gratings (left & right oblique orientations) at 1.4 cpd, and 3.8 degree size. Luminance contrast was 70% or 100%. For binocular rivalry, images were presented dichoptically (with polarizers) with short blank periods, stimulus flicker at 5.6 Hz. For stimulus rivalry, the stimuli were identical except that the images shown to each eye were swapped at 5.6 Hz. Another similar condition created stimulus 'quilts,' by presenting half of one grating to one eye and the other half to the other eye, to increase the demands on interocular grouping. Subjects performed a rivalry report task. We find that alternation rates do not differ for the binocular and stimulus rivalry conditions, for both intact and quilted stimuli, suggesting a common mechanism at the binocular stage for both conditions (average alternation periods were 1.4, 1.6, 2.2, and 2.2 sec respectively for binoc/intact, stim/intact, binoc/quilt, and stim/quilt). This result holds with flicker rates slow enough to defeat monocular masking. Alternation rates are modestly slower for both the quilted conditions. This is consistent with greater grouping demands and possibly a greater network contribution from higher visual areas. Future fMRI work could test hypotheses regarding the neural sites of binocular versus stimulus rivalry, monocular or binocular masking, and interocular grouping.

Acknowledgement: NSERC Discovery Grant CFI-LOF

Binocular vision: Stereopsis

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

23.511 **Constraints on perceiving camouflage in da Vinci stereopsis**

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In 3D binocular scenes, parallax results in different occlusion relations between near and far surfaces in the two eyes. Monocular (unmatched) regions at the side of binocular surfaces can support a compelling perception of depth, known as "da Vinci" stereopsis. When the monocular region is nasal in the visual field it is seen behind the binocular surface, consistent with occlusion of a partner image in the other eye, and when temporal it can (more controversially) appear in front, consistent with camouflage of a partner image against the binocular surface. In these experiments we examine the latter situation that would seem to require ecologically not only the correct geometry but also a color match of the monocular region and the binocular surface. Naive observers matched the perceived depth of a rectangular monocular tab attached to a circular binocular shape by adjusting the binocular disparity of a small probe. Observers perceived quantitative depth in both occlusion (far) and camouflage (near) arrangements for a monocular black tab attached to a black binocular figure. However, when the tab was red and violated the viewing constraints for camouflage, depth was only perceived for occlusion. In a binocular control experiment, observers matched the depth of a binocular tab that was colored black in one eye and red in the fellow eye, demonstrating that the monocular tab results were not a consequence of binocular rivalry. No depth from camouflage was perceived when the monocular region was a bar next to the binocular region, indicating that attachment to the binocular figure is critical. This reflects contradictions in the literature between for example von Szily (1921) who used tabs and Nakayama and Shimojo (1990) who used bars. We conclude that da Vinci stereopsis not only involves the sophisticated application of occlusion geometry but also novel matching constraints.

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23.512 **Is depth in monocular regions processed by disparity detectors? A computational analysis.**

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Depth from binocular disparity relies on finding matching points in the images of the two eyes. However, not all points have a corresponding match since some regions are visible to one eye only. These regions, known as monocular occlusions, play an important role in stereoscopic depth perception supporting both qualitative and quantitative depth percepts. However, it is debated whether these percepts could be signaled by the activity of disparity detectors or require cells specifically tuned to detect monocular occlusions. The goal of the present work is to assess the degree to which model disparity detectors are able to compute the direction and the amount of depth perceived from monocular occlusions. It has been argued that disparity-selective neurons in V1 essentially perform a cross-correlation on the images of the two eyes. Consequently, we have applied a windowed cross-correlation algorithm to several monocular occlusion stimuli presented in the literature (see also Harris & Smith, VSS 2010). We computed depth maps and correlation profiles and measured the reliability and the strength of the disparity signal generated by cross-correlation. Our results show that although the algorithm is able to predict perceived depth in monocularly occluded regions for some stimuli, it fails to do so for others. Moreover, for virtually all monocularly occluded regions the reliability and the signal strength of depth estimates are low in comparison to estimates made in binocular regions. We also find that depth estimates for monocular areas are highly sensitive to the window size and the range of disparities used to compute the cross-correlation. We conclude that disparity detectors, at least those that perform cross-correlation, cannot account for all instances of depth perceived from monocular occlusions. A more complex mechanism, potentially involving monocular occlusion detectors, is required to account for depth in these stimuli.

Acknowledgement: NSERC

23.513 **On the allocation of attention in stereoscopic displays**

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It has been shown that disparity can be used as a token for visual search (possibly pre-attentively). However, there has been no systematic investigation of the distribution of attentional resources across the disparity dimension. Here we evaluated whether position in depth, relative to the screen plane, influences attentional allocation. We conducted two experiments using the same visual search task but with different stimuli. In the first experiment, stimuli consisted of four simple geometric shapes and in the second experiment the stimuli consisted of four orientated lines enclosed by a circle. In both cases, the stimuli were arranged in an annulus about a central fixation marker. On each trial, observers indicated whether the target was present or not within the annular array. The distractor number was varied randomly on each trial (2, 4, 6, or 8) and the target was present on half of the trials. On all trials, one element had a disparity offset by 10 arcmin relative to the others. On half of target present trials the target was in the disparate location, on the remainder it was presented at the distractor disparity. Trials were further subdivided such that on equal numbers of trials the disparate element was on or off the plane of the screen. We measured search time, analysing only trials on which observers responded correctly. Both experiments showed that when the target was the disparate item, reaction time was significantly faster when the target was off the screen plane compared to at the screen plane. This was true for a range of crossed and uncrossed disparities. We conclude that there exists a selective attentional bias for stimuli lying off the screen plane. These data are the first evidence of a disparity-selective attentional bias that is not mediated by relative disparity.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

23.514 The effect of expectancies on stereoacuity

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Classical conditioning can be used to teach the visual system to use new cues to bias visual percepts (Haijiang et al., PNAS, 2006). In the present study we investigated whether expectancies on the depth of a visual object can influence sensitivity to perceive its fine structure. To test this possibility, we measured stereoacuity: participants were asked to judge the relative depth of two black lines presented 0.2 degrees apart on a grey background for 200 ms. A 400 ms pure tone was presented starting 200 ms before the presentation of the visual stimulus. Participants were told to ignore the auditory tone and focus on the visual task. An adaptive staircase procedure was used to measure the disparity threshold corresponding to 75 percent correct performance. Stereoacuity was measured in four interleaved experimental conditions. Test lines were presented either behind (at a mean disparity of -15 arcmin) or in front (+15 arcmin) of a frame. When in front, the lines were accompanied by a high pitch sound (660 Hz pure tone) in 75% of the trials (expected condition) and by a low pitch sound (440 Hz) in 25% of the trials (unexpected condition). When behind, these proportions were reversed. Among seven participants tested, five showed shorter response times in the expected condition, indicating an efficient association between pitch and mean disparity. For three of these successfully associated participants we observe a trend for a worse sensitivity for the unexpected condition compared to the expected condition. These results suggest that the stereoscopic system is able to learn cues to predict the position of objects in depth and to use this prediction to increase its sensitivity.

23.515 Occlusion-based stereopsis with alternating presentation of the stereo half images

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Recently, it was reported that stereoscopic phenomena, including stereopsis and binocular luster, could be differentiated according to dichoptic alternation frequency thresholds (Ludwig, et al., 2007, AP&P 69(1), 92-102; Rychkova & Ninio, 2011, iPerception (2), 50-68). In these studies, left and right eye images were alternated at various rates and the threshold was defined as the minimum alternation frequency for which participants reliably reported depth or luster. In these two studies, alternation thresholds for various stereoscopic phenomena ranged from approximately 3Hz to approximately11Hz. We applied this technique to explore temporal integration for several occlusion-based stereoscopic phenomena (e.g. da Vinci stereopsis (Nakayama & Shimojo, 1990, Vis Res 30(11), 1811-1825), monocular gap stereopsis (Gillam et al., 1999, Vis Res 39(3), 493-502), and phantom stereopsis (Anderson, 1994, Nat 367, 365-368)). Perceived depth in these stimuli is thought to result from the binocular combination of non-corresponding monocular occlusion zones that are geometrically consistent with an occlusion resolution. Participants viewed alternating dichoptic images in a mirror stereoscope. Each stereo-pair depicted two depth orders of the same stimulus, separated spatially. One depth order was geometrically consistent with a nearer target and the other was either consistent with a farther target or inconsistent with occlusion altogether. Using the method of adjustment, participants either increased the alternation rate of the stereo half images until they could identify which of the two stimuli depicted the surface arrangement with the nearer target, or they reduced the alternation rate until they could not make this discrimination. We computed mean alternation rates between randomized ascending and descending trials for each participant. Depth discrimination was reliable across a range alternation rates from approximately 3Hz to approximately 10Hz. Temporal integration of alternating stereo half images of occlusion-based stereograms differs across occlusion-based stereo phenomena but falls within the range observed for disparity-based stereopsis and binocular luster.

23.516 Fine and coarse stereopsis follow different developmental trajectories in children

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Stereoscopic depth perception may be obtained from small retinal disparities that can be fused for single vision (fine stereopsis), but reliable depth information is also obtained from larger disparities that produce double vision (coarse stereopsis). The role of coarse stereopsis in vision is not well understood, but it may develop early in life to guide vergence eye movements that are necessary for the development of fine stereopsis. While there is some evidence that stereoacuity improves with age, little is known about the development and maturation of coarse stereopsis. The purpose of this study was to determine the age at which performance on fine and coarse stereoscopic tasks reaches adult levels during typical visual development. We compared performance in children (4-13 years) and adults on computerized tests of fine and coarse stereopsis. All participants had normal visual acuity, normal stereoacuity and no ocular pathology. Stereoscopic stimuli were presented using liquid crystal shutter glasses. The observer's task was to indicate whether a cartoon character was nearer (crossed disparity) or farther away (uncrossed disparity) than a zero-disparity fixation marker. We assessed perceived depth for a set of fine disparities that were within Panum's fusion zone (0.02, 0.08, 0.17, 0.33, 0.67, 1 degrees) and a set of coarse disparities that appeared diplopic (2, 2.5, 3, 3.5 degrees). Accuracy increased with disparity in the fine range and decreased slightly with disparity in the coarse range for all participants. Within the coarse range, there were no differences between age groups. However, performance was immature until age 12, at the finest disparity tested; adult levels were reached at different ages across the other disparities in the fine range. These results suggest that coarse stereopsis matures before 4 years of age, but fine stereopsis continues to mature into the school-age years.

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23.517 What's captured in Binocular Capture: Envelope or carrier?

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The perceived visual direction of a monocular target is displaced toward the cyclopean visual direction of surround targets. The monocular target seems to be particularly susceptible to the visual direction of the surround when stimulus conditions favor the recruitment of "local-sign" based position mechanisms. This study extends this observation by measuring the alignment bias of a monocular pair of vertically separated Gabor targets presented within a 10′ random dot stereogram depth edge. METHODS: Alignment bias was measured for conditions in which the relative offset between the monocular Gabor pair was defined either by horizontal shifts of the envelope only (EO) (carrier comprised horizontal cosine gratings) or by horizontal phase shifts of the carrier only (CO) which comprised vertical cosine gratings (1, 2, 4 & 8 cycles per degree). Alignment bias was also measured for a Gabor target comprising a vertical 1-cpd square-wave grating (SQ) and a 1-cpd vertical missing fundamental (MF) square-wave grating. Alignment bias was measured for each condition (CO, EO, SQ and MF) across four (8, 30, 60, 120 arc minute) vertical separations. RESULTS: Alignment bias increased with vertical separation and scaled proportionally with alignment threshold for the EO condition but not for the CO condition. Alignment bias also increased with vertical separation and scaled proportionally with alignment threshold for the MF condition but not for the SQ condition. CONCLUSIONS: These results strongly suggest that higher-level feature-based position mechanisms are more susceptible to capture by the surround visual direction compared to first-order spatial frequency based position mechanisms. When higher-level feature-based position mechanisms are recruited, positional uncertainty plays a key role in determining the magnitude of capture.

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23.518 **Representation of Stereoscopic Volumes**

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Binocular disparity provides the human visual system with estimates of both the three-dimensional shape of surfaces, and of the depth between them. Additionally, binocular disparity cues provide a compelling sense of the volume occupied by objects in space. However, studies of stereoscopic vision have tended to examine the perceived depth of isolated points, or the perceived structure of surfaces in depth, without addressing the associated sense of volume. Comparatively little is known about how the visual system represents stereoscopic volumes. The experiments reported here address this issue by examining observers' ability to judge changes in the range and distribution of disparity-defined volumes of dots. Observers were presented with Gaussian distributed random-dot volumes in a three interval, odd-one-out detection task. Each interval was presented for 200ms, and contained a stereoscopic volume within an area of 4.8 x 4.8 degrees. In two (standard) intervals, dot disparities were drawn from a Gaussian distribution of fixed standard deviation 1.1arcmin. In the third (target) interval a proportion of dot disparities were drawn from a uniform distribution with a range of between ±1.1arcmin and ± 7.7arcmin, with the remaining dots drawn from the same Gaussian distribution as the standard intervals. For some ranges, an entirely uniform distribution could not be distinguished from the Gaussian standards. Instead, the ability to detect the odd interval depended largely on the range of the distribution, not its shape. Changes in dot density, and in the standard deviation of the Gaussian distribution did not lead to a general sensitivity for distribution shape, but instead resulted in changes to the range of uniform distributions where the target interval could not be reliably detected. Our results suggest that the visual system makes use of an impoverished representation of the structure of stereoscopic volumes.

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23.519 **Contours and Surfaces Affect Stereoscopic Depth Perception in Dynamically Specified Displays**

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Background: Disruption of contour relatability in depth blocks unit formation (Kellman, Garrigan & Shipley, 2005), but recent work in 4D interpolation (combining 3D and spatiotemporal unit formation) has produced mixed findings (Erlikhman, Ghose & Kellman, VSS 2011). The latter studies used object fragments specified over time by occlusion of small background elements (c.f., Palmer, Kellman & Shipley, 2006). Question: One hypothesis about equivocal results in 4D is that subjects may not register stereoscopic depth veridically in these displays; depth perception may be affected by an interaction between contour completion and dynamic specification of object parts. Method: Display objects were pairs of black squares or circles that were vertically aligned. Subjects adjusted the disparity of one object until they felt it matched the depth of the other. In one stationary and one lateral movement condition, the black objects were fully visible against a red background. In a third condition, the black objects matched the background and were visible only via progressive occlusion of small, red, rectangular inducing elements. The objects were separated by three possible dividers: none, a green rectangular strip abutting each object, or a similar, black strip. For squares, when the divider was black, completion was possible. Results: We tested 10 subjects who passed a demanding stereoscopic depth test. Depth adjustments were highly precise for fully specified, stationary and moving shaped. Variability in adjustment error increased to 13-28 arcmin of disparity when objects were dynamically specified. There was an interaction with background condition. Either presence of a visible divider (interfering with completion) or contour relatability (squares) appeared to be responsible for inaccurate depth perception. Conclusion: Dynamically specified object fragments have unstable stereoscopic depth that may be easily affected by nearby contours and surfaces. These results place constraints on the depth sensitivity of 4D interpolation.

23.520 **Temporal Characteristics of Stereomotion Direction Perception**

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Previous research has shown that there are two binocular cues that contribute to the perception of motion in depth. One cue consists of the rate of changing disparity (CD) over time and the other consists of interocular velocity difference (IOVD). In the current study, we examined the temporal characteristics of the two cues in determining motion in depth perception. In the study, uncorrelated random dot stereograms (URDS) were used to present displays with IOVD information only, and dynamic correlated random dot stereograms (DRDS) were used to present displays with CD information only. The life time of the random dots was manipulated in both URDS and DRDS display conditions. Observers were asked to judge the direction of motion in depth. The results showed different temporal response curves for displays with CD information as compared to those with IOVD information. This suggests that different temporal characteristics of CD and IOVD information need to be taken into account when investigating stereomotion perception.

23.521 **A Comparison of Self-Reported and Measured Autostereogram Skills with Clinical Indicators of Accommodative Function**

Patricia Cisarik[1](pcisarik@sco.edu), Bret Butterfield[1]; [1]Southern College of Optometry

To fuse an autostereogram, the intersection of the viewer's visual axes must occur in front of or behind the plane of the physical stereogram to attain the vergence angle necessary to place the left and right images on corresponding areas of the two retinas. Accommodation, however, should remain in the plane of the physical autostereogram for clearest perception of the disparity-defined form. The direction of decoupling of accommodation and convergence needed for autostereogram fusion is in the direction opposite that typically found with observers under normal viewing conditions. Our previous work compared common clinical indicators of vergence ability with subjects' self-reported and measured autostereogram skills and found significant differences between those with poor versus good self-reported and measured autostereogram skill for vergence facility, near phoria, and TNO stereoacuity. The present study was undertaken to compare clinical indicators of accommodative function to self-rated and measured autostereogram skills. Our results show that subjects whose self-rated autosterogram skills were "poor" did not demonstrate statistically significantly poorer performance on any of the clinical tests of accommodative function. Subjects whose measured autostereogram skills were "poor" demonstrated statistically significantly poorer performance compared to subjects with "excellent" measured autostereogram skills only on amplitude-adjusted accommodative facility; however, the differences were not clinically significant. A statistically and clinically significant difference in symptom scores on the CISS manifested between the groups who self-rated "poor" versus "excellent" on autostereogram skills, but not between the groups who measured "poor" versus "excellent" on autostereogram skills. These results suggest that difficulty with fusing autostereograms is not likely due to an underlying accommodative dysfunction.

23.522 **Effects of monocular distractors on monocular and binocular visual search.**

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Our visual systems integrate information from the two eyes to form a stable and continuous percept of the world around us. However, not all of this information is binocular. Because objects are often partially occluded by other objects, there are a host of monocular regions as well as the binocular regions surrounding them. Here we ask whether this monocularity affects our visual search performance, when we are searching for a monocular or a binocular target. In a reaction time experiment, participants were asked to find a target 'C' amongst 224 distractor O's as quickly as possible. The target C was presented in one of 2 conditions: 1) monocular b) binocular. For each condition the number of monocular distractors was varied between zero and 32. All other distractors were presented binocularly. For the monocular condition, we found very fast reaction times with 0 and 1 monocular distractors. Reaction times increased logarithmically as the number of monocular distractors increased. For the binocular condition, reaction times were initially slower than for the monocular condition, but did not increase significantly with number of monocular distractors. The spread of participants' reaction times mirrored this pattern with an increase in the variance of reaction times in the monocular target condition and a stable variance in the binocular target condition. Monocular distractors appear to disrupt our visual search when searching for a monocular target, but not when searching for a binocular target. It appears we able to ignore monocular information if it is task-irrelevant.

3D perception: Shape from shading and contours

Saturday, May 12, 8:15 - 12:15 pm
Poster Session, Vista Ballroom

23.523 Inferring 3D Surface Shape from 2D Contour Curvature

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Boundary shape alone (e.g. in silhouettes) can be a strong perceptual cue to the 3D shape of a smooth object. Certainly the sign of curvature of the bounding contour strongly constrains the 3D shape of the surface at the rim: convex points on the boundary project from convex surface points, whereas concave points project from surface saddle points (Koenderink & van Doorn 1976; Koenderink 1984). Furthermore, when curvature changes smoothly over the surface of an object, these boundary constraints may also carry information about the qualitative shape of the 3D surface interior to the boundary. Here we ask whether the magnitude of curvature of the bounding contour might also contribute to the perceived 3D shape on the interior surface of an object. We generated random 3D shapes by adding Perlin noise to spheres. Objects were partially occluded such that a wedge segment of the object was visible. In separate trials, the bounding contour was either visible or occluded. Observers adjusted the depth of a binocularly viewed dot so that it was perceived to lie on the surface. We found that when direct surface shading and disparity cues were weak, the perceived surface shape on the interior of the object was modulated by the magnitude of curvature of the bounding contour. When direct cues to surface shape were strengthened, this boundary effect was substantially reduced. We conclude that the influence of the bounding contour on the perception of 3D object shape derives not just from the sign of curvature but also its magnitude. We discuss this finding in terms of the ecological statistics of 3D curvature and projected contours of objects in our visual environment.

23.524 "To bite, or not to bite": Perceived causality in the perception of negative parts

Patrick Spröte[1](patrick.sproete@googlemail.com), Roland Fleming[1]; [1]Justus-Liebig Universität Giessen

Most research on 3D shape perception has focused primarily on how the brain estimates local shape properties such as depths, surface orientations or curvatures. However, the phenomenology of perceived shape can involve much more than local surface geometry. When we look at a bitten apple, we not only estimate local shape properties, but also segment the shape into distinct parts with different functional meanings (stem, fruit, bite). We can often assign different causal origins to different portions of the shape. For example, we readily interpret the bite as being due to a different generative process than the rest of the apple, as if part of the apple were removed from some 'original' or 'authentic' shape. Here, we studied the geometrical properties that cause concave regions ('negative parts') to be interpreted as 'bites' that have removed some portion of an object, rather than intrinsic to the object's natural form. We used convex, irregular hexagons to measure if and how subjects infer the causal history of unfamiliar 2D shapes. Half of the stimuli were 'bitten', by randomly intersecting them with another hexagon and deleting the overlap. We asked subjects to rate on a 10-point scale the extent to which each stimulus appeared to have been bitten. Our data show that subjects can do the task surprisingly well even though the stimuli are ambiguous. We propose several visual cues that subjects might use, such as the ratio between the width and depth of the negative part: the deeper and narrower a negative part the more likely that the shape was perceived as being bitten. We further discuss similarities and distinctions between the detection of bites with occlusion and camouflage. These also cause parts of objects to be missing from the image, but are subject to different physical constraints.

23.525 A computational model of recovering the 3D shape of a generalized cone

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Recovering a 3D shape from a single 2D image is an ill-posed problem. However, our previous studies (e.g., Li et al., 2011) showed that subjects perceive shapes of mirror symmetric objects accurately even from a single 2D image. Our computational model, in which 3D mirror symmetry is the main a priori constraint, recovers 3D shapes the way human subjects do. Here we generalize these previous results to the case of "translational symmetry". 3D objects which are characterized by translational symmetry are called generalized cones (GC), and were used by Biederman in his RBC theory (1987). In this study, GCs were produced by swiping a planar closed curve (cross section) along a planar curved axis with the following constraints: all cross sections in a given GC had the same shape, but not necessarily size. Each cross section was perpendicular to the tangent of the axis. Last year we showed that the subject's percept of such GCs is close to veridical. Specifically, the subject was able to adjust quite accurately the aspect ratio of the cross section of a GC and the slant of the plane containing the axis of the GC. This year, we describe a computational model which can solve the same recovery task from a single 2D orthographic image. The model uses the constraints listed above. The recovery is done in two steps: (i) the shape of the planar cross section and the slants of the two end cross sections are recovered from the images of these cross sections and from the estimated tilts; (ii) the normal of the plane containing the axis is computed as a cross product of the normals of the two end cross sections. The model's recovery is strongly correlated with the subject's recovery and both are close to the true 3D shape.

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23.526 Visual aftereffects in 3D shape and material of a single object

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Recent psychophysical studies utilize adaptation effects to probe the functional representations underlying the perception of complex stimuli such as faces, scenes, and surfaces. Here, we applied an adaptation paradigm for the perception of 3D shape (and material) of a realistic object, and show robust aftereffects for a wide range of attributes. We used computer-generated images of a spherical object that was deformed according to a radial map of band-pass noise of variable frequencies (1-32 cycles/pi) and amplitudes. The deformations at different frequencies resulted in global shape distortion (low), bumpiness (mid), and surface roughness (high). Several material properties, diffuse and specular reflectance and translucency, were also manipulated. In the experiment, the observer first viewed an adapting object for 10 sec. The object was repeatedly flashed for 250 ms at either the left or right side of a fixation point. Different adapting stimuli had particular shape and material parameters; e.g., light, glossy, opaque, and very bumpy. On each trial following top-up adaptation of 3 sec, the test and comparison objects were presented for 250 ms at the adapted and non-adapted location, respectively. The observer compared a particular attribute between the two objects (e.g., which object appears bumpier), and the PSE estimated along a given parameter dimension (e.g., deformation amplitude). It was found that the perceived shape distortion, bumpiness, roughness, lightness, glossiness, and opacity were dramatically reduced following adaptation to an object that had a higher value in that attribute. Adaptation to lower values enhanced the perception of some attributes. The aftereffects were also induced by textures on a matte sphere, or even by a simple band-pass noise image. These results imply an important role of low-level summary statistics not only in material perception, but also in global 3D shape perception.

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23.527 Learning to use illumination gradients as shape cues.

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Gradients such as shading and interreflections contain information about shape and scene structure. As with other cues to shape, the information in the gradients is ambiguous and the visual system requires constraining

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information to make use of it. We investigated whether sufficient information to disambiguate gradient depth cues is available as visual priors, or if aspects of the visual scene (e.g. light position), must be learnt in order to effectively use the gradient information. Stimuli consisted of rendered, physically accurate, cards with one side white, one red, separated by a vertical fold to form a concave or convex shape. Participants set shape estimates for stimuli at a range of card angles. Cues to depth other than gradients, such as binocular disparity and object outline were minimised by the use of a viewing aperture. Four observers received only a verbal explanation of the task ('no training'), six saw a 30s video showing the full range of shaded stimulus angles with a congruent object outline and correct settings ('full training') and four saw a similar video but with incongruent gradients corresponding to the inverse shape ('incongruent training'). Observers only participated in one condition. Results show that observers could not make accurate shape settings without seeing a representation of the stimulus beforehand. The 'full training' condition was however sufficient for observers to make consistent and unambiguous settings. This result could arise if observers made settings based on a mapping of gradients learnt from the video, but the results of the 'incongruent training' do not support this as three of the four participants made settings similar to those in the 'full training' condition. Our results indicate that that the visual system is capable of using complex illumination gradients as a depth cue, but that priors alone are not sufficient to disambiguate the gradients.

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23.528 **Orientation fields in shape from shading**

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The interaction of shape, material and lighting creates complex patterns of orientation in the image, which play an important role in 3D surface estimation. Depending on the nature of these orientation fields, different cues can be extracted: the orientation fields produced by textured objects carry information about the 3D orientation of the surface (i.e. first order properties), while shading is compressed and stretched depending on the second-order (curvature) properties of the shape. Here, we investigate the relation between shading flows and the perception of shape. We show that by locally modifying the orientations in images of shaded surfaces, we are able to substantially alter the perceived shape. We performed two experiments in which subjects had to match the perceived shape of a test stimulus. In the first experiment, stimuli were generated by adding high frequency patterns (HFPs) on top of diffuse shading. HFPs were oriented along the principal curvature directions of the surface, by 'smearing' noise using line integral convolution. Results show that, depending on the smearing intensity and on the chosen curvature direction (i.e., minimal or maximal), surface features appeared to be either sharpened or rounded respectively. In the second experiment, we used an image processing operator to control the behavior of low-frequencies (LF) shading orientations. By distorting LF gradient patterns on a surface according to curvature information, we are able to precisely control the orientation field in an image. We show that the more a feature is aligned with the shading orientation, the less subjects are able to perceive it correctly. These experiments show that there is a direct relationship between shading orientation flows and our perception of surface curvature, implying that image orientation measurements play a key role in the estimation of shape from shading.

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23.529 **Qualitative shape from shading, specular highlights, and mirror reflections**

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Surface appearance cues such as shading and specularities provide a rich source of information about 3D shape. Here we present an experiment that compared qualitative shape perception from such cues. We used OpenGL to render smooth bumpy terrain surfaces under perspective projection and under several rendering models, including the Phong model with a point light source and a mirror reflection model with a complex orientation-free environment. Each rendered terrain surface had a floor slant of 30 degrees consistent with a view-from-above prior, and each was presented either statically or rotating. The task was to judge whether a marked point on each surface was on a hill or in a valley. Percent correct scores (12 observers) were highest in the 'Lambertian only' condition, lower in the 'mirror only' and 'broad highlight only' conditions, and lowest in the 'narrow highlight only' condition. No effect was found for rotating vs. static presentation. The results are somewhat inconsistent with (Norman et al, Psych. Sci. 2004) who found that highlights improve performance in a shape discrimination task. The results are more consistent with (Fleming et al, J. Vision, 2004) who found that specularities can provide shape information if they produce a dense set of image gradients that covary with the second derivatives of depth. This requirement was met by all the rendering models above, except for 'narrow highlights only'.

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23.530 **Shape-from-Shading and Cortical Computation: a new formulation**

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Although humans exhibit a substantial ability to interpret shape from shading variations, there exists no biologically plausible computation to explain it. Instead, in computer vision, shading analysis is normally formulated as a first-order non-linear partial differential equation that relates surface normal distributions to image intensities. The equation is difficult to solve in natural scenes, initial conditions and light source locations are difficult to obtain, and there is no connection to neurobiology. In contrast, we are developing a new approach to shape from shading that is built directly upon the information available in visual cortex. Furthermore we solve for the surface and light sources together. We start with the shading flow–the cortical representation of projected surface isophotes– and supplement this with contrast variation. We then introduce a novel mathematical formulation for calculating local surface shape in a manner that could be implemented by cortical computations. It is based on covariant derivatives, a shape operator based on curvatures, and yields a differential form that plays an analogous role to co-circularity in curve inference. Although far more complex, it could therefore be implemented by feedback or long-range horizontal connections in cortical columns. The heart of the computation is the second fundamental form and how this relates to the shading flow. Assuming constant albedo, we are able to solve exactly for the light source/surface pairs needed for a local image patch to have a given shading flow. The magnitude of the brightness gradient restricts this family to a single light source and surface estimate for that image patch. We observe properties regarding the interplay between the shading, light source, and surface parameters. In ambiguous cases, the lighting-from-above assumption corresponds to a surface convexity assumption. Also, for unknown ellipsoids, one can relate the angular changes in the flow to the ratio of principal axes.

23.531 **The effects of lighting direction and elevation on judgements of shape-from-shading.**

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Knowledge of the lighting direction is crucial in recovering shape-from-shading. Many studies have shown that we adopt a lighting-from-above assumption when the true lighting direction is unknown or ambiguous. Others have shown that perceived lighting direction depends on the orientation structure in the shading pattern itself. Many studies have tested the effects of lighting azimuth variations on the perception of shape-from-shading. We test the effects of varying the declination (elevation) of the light source. We generated images of three different surfaces (differing in their degree of anisotropy) illuminated with spotlights at 6 angles of declination (0°, frontal to 75° degrees, oblique) with constant azimuth. These surfaces were generated from Gabor noise textures with surface heights determined by the 'grey' values of each texture. We tested images at two orientations: upright (with the surface lit from the right), or rotated (lit from above). Varying declination affected the contrast of the resulting shading patterns so we also tested images after normalising their RMS contrasts. Observers set the tilt and slant of a probe disk to match the perceived 3D surface orientation. We obtained observations at nine locations per image. We found that tilt setting for the most anisotropic surface depended on image orientation whereas for the isotropic surfaces tilt was determined by the lighting-from-above prior. Slant settings tended to increase in proportion to local luminance/contrast, and normalising RMS contrast greatly reduced the range of slant settings. In conclusion we found that shape judgments in isotropic shading patterns are more affected by the lighting-from-above-prior than those for anisotropic surfaces and that slant judgments depend on local luminance/contrast and are affected by changes in the declination of the light source; when this affects the contrast of the shading pattern.

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Motion: Optic Flow

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

23.532 **Effects of flow field noise and density on optic flow parsing**

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We have previously suggested that neural flow parsing mechanisms, which subtract global optic flow consistent with observer movement, play a role in recovery of scene-relative object movement. In this study, we investigate how the quality (noise) and amount (density) of information in the optic flow field (OFF) affect flow parsing. We predict that since flow parsing involves global motion processing it should be relatively robust to noise and density manipulations. Participants fixated at the centre of a radial flow field of limited lifetime dots, and were asked to judge the direction of motion of a laterally displaced probe moving vertically upwards. To limit the contribution of local motion processing mechanisms, no flow field dots were presented in a patch of radius 3 deg centred on the probe. The 2D motion directions of the dots were subject to three levels of zero mean additive Gaussian noise (s.d. = 0, 7.5, or 15 degrees). We also varied the density of the OFF by changing the instantaneous number of dots on screen (5, 50, 100, 200 dots). We measured the relative tilt of the probe (the angular difference between the physical probe direction and the perceived direction). Analyses revealed a relatively small (although significant) decrease in the magnitude of the realative tilt effect with the increased noise (on the order of 10-20%). With respect to the density manipulation, although the relative tilt effect was significantly reduced in the lowest density condition, it was stable over all other dot densities. These data suggest that, as anticipated, flow parsing is relatively robust to variations in noise and density. The data are broadly in line with results for heading recovery when noise and density are manipulated. This provides some evidence that flow parsing and heading recovery share common mechanisms.

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23.533 **Role of Occipital Cortex in the Perception of Depth-order from Motion: A Human fMRI Study**

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When one visual object moves behind another, it provides a compelling sense of which object is closer to the viewer and which object is farther in depth. This percept is referred to as depth-order from motion (DFM). The neural mechanisms of DFM are largely unclear, including the relative roles of the first-order (i.e., luminance-based) vs. the second-order (i.e., non-luminance-based) motion processing mechanisms, and the relative contributions of the two known types of DFM cue, the accretion-deletion (AD) cue and the common motion (CM) cue. To help elucidate the neural mechanisms of DFM perception, we performed a human whole-brain fMRI scan using a mixed (i.e., events-within-blocks) design, which allowed us to compare the responses across blocks as well as across individual trials. Depending on the stimulus block, subjects viewed random dot stimuli that either elicited strong depth-order percepts (DFM stimuli) or did not (null stimuli). Subjects reported the perceived depth-order using a button press. The DFM stimuli contained both types of DFM cue, whereas the null stimuli contained neither cue. The two sets of stimuli were otherwise identical, including in terms of average luminance, contrast, and motion energy. The only brain region that showed a significant activation in all subjects ($N = 21$; $p < 0.05$, corrected for multiple comparisons) was a bilateral occipital region that partially overlapped with the kinetic occipital region (KO), previously known to be involved in the processing of motion borders. Similar results were obtained when real-world 2-D photographs were used as DFM stimuli, indicating that the responses were not stimulus-dependent. Importantly, the responses of this region varied systematically with the strength of DFM information in the stimuli, and the DFM percept they elicited, on a trial-to-trial basis. Together, these results indicate that this occipital region plays a key role in DFM cue processing and DFM perception.

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23.534 **Both changes in projected size and speed affect the judged height of objects moving over a ground surface**

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Kersten (1997) showed that the perceived motion path of an object in a 3D scene can be manipulated by changing the path of a shadow. Using a scene similar to Kersten's "ball-in-a-box" scene, we considered two other variables affecting the perceived path: changes in projected size and changes in projected speed. We expected an object to appear to move higher if the projected size or speed increased while ground contact indicated recession in depth. Each scene began with a stationary ball on a platform at the lower left of a surface extended in depth with two vertical sidepieces. The ball moved toward the upper right of the surface and disappeared. Observers were asked to mark the height at which the center of the ball would have hit the right sidepiece. The ball's projected path was identical in each display. There were three levels of projected size change: decreasing (consistent with recession in depth), constant (consistent with motion in 2D) and increasing (the reverse of the decreasing function). The three levels of speed change were the same. The judged height at which the ball would intersect the right sidepiece was affected significantly by both the projected size and speed functions. Judged height was greater with increasing speed than with either decreasing or constant speed. Judged height was greater with increasing projected size than with constant projected size and was greater with constant projected size than with decreasing projected size. In addition, the final size and speed were important in determining the judged height at the end of the motion sequence with greater height judged for larger final projected sizes and speeds. These results indicate that size and speed changes inconsistent with the depth change indicated by ground contact results in the perception of an object as rising above the ground surface.

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23.535 **The role of presentation and depth singletons in the prioritization of approaching but not receding motion in depth**

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When examining motion in depth and the attentional system, previous studies have reported conflicting results, with some finding attentional prioritization for only approaching motion (Franconeri & Simons, 2003), and others reporting capture for both approaching and receding motion in depth (Skarratt, Cole, & Gellatly, 2009). This discrepancy could be due to at least two factors: 1) differences in the way in which motion in depth was simulated, or 2) a confound between motion in depth and the initial unique depth of the moving object relative to the other distractors. We addressed these factors in two experiments. We used a search paradigm comparing the response time to find a target when it did or did not spatially coincide with the endpoint of an object's approaching or receding motion. In Experiment 1 we simulated motion in depth using size scaling, binocular disparity, or a combination of the two. The pattern of response times varied with the method used, indicating that the method used to simulate motion in depth is an important factor for this effect. Experiment 2 controlled for the initial depth of the moving target by comparing a condition with the depth singleton removed by spreading items over two depth planes, to a condition with a single depth plane and a depth singleton. We observed shallower search slopes for targets coinciding with an approaching item than a static item in both conditions, as well as speeded response times to approaching motion compared to receding or static targets. Slopes for receding motion were shallower than for static targets only when the moving stimulus constituted a depth singleton. We conclude that low level visual processing of approaching motion is more efficient than for receding motion, and this rapid low level visual processing can increase the salience of approaching motion.

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23.536 **The motion of form features provides a cue to angular velocity**

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A location along the contour of a rotating object possesses both an angular velocity, which is the same at every location along the contour, and a linear velocity, which is dependent on contour location's distance from the center of rotation. The question we address here is whether we perceive the angular velocity, linear velocity, or some combination of the two when viewing a rotating object? To address this question we examined how the size of an object influences how fast it is perceived to rotate. If we perceive the angular velocity of a rotating object, then changing its size should not influence how fast it is perceived to rotate. However, as an object becomes smaller, all of the local translational velocities will decrease. Thus, if we perceive the translational velocities of an object, we would expect smaller objects to appear to rotate more slowly than larger ones. A series of psychophysical experiments examined the influence of size on perceived rotational speed for a variety of different object shapes: ellipses, rectangles, rounded rectangles, and stars. Overall, larger shapes were perceived to rotate faster than smaller shapes with the same angular velocity, indicating that observers do not perceive the angular velocity of a rotating object. However, the shape of the object influenced the relationship between size and perceived rotational speed. Specifically, the perceived speed of objects with distinct contour features, such as corners or regions of high curvature, were influenced to a lesser degree by changes in size. Conclusion: the perceived speed of a rotating object is mediated by a combination of two sources of motion information. The first is based on the locally detected component motion and represents linear velocity and the second is based on the motion of distinct form features and represents angular velocity.

23.537 **Visual and non-visual contributions to perception of object movement during observer movement**

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Accurate estimation of object movement is difficult for moving observers, since it is unclear whether to attribute retinal motion to movement of the object or observer. Recently, we have proposed a purely visual neural mechanism ('flow parsing') which aids in this process by attempting to globally filter retinal motion due to observer movement. Here we investigate the contributions of visual and non-visual information to object movement perception during pursuit eye movements. Participants tracked a pursuit target amongst a background of stereoscopically presented wireframe objects and made judgements about the trajectory of a probe dot moving vertically upwards on the retina (assuming perfect tracking of the target). Eye movements were recorded and trials on which tracking was poor were excluded. Extra-retinal (E) movement information was manipulated by changing the target speed. Retinal (R) movement information was manipulated by changing the relative speed between the target and background. Using a 2IFC procedure, on each trial participants saw the reference stimulus, for which R and E were in conflict (E = 3 deg/s; R = 5 deg/s – achieved by moving the background in the opposite direction to the target at 2 deg/s) and a comparison stimulus, for which R and E were equal (E = R = 1, 2,..., 7 deg/s). Participants judged the interval in which probe movement was more vertical. If probe trajectory perception was based on extra-retinal information alone then the PSE of the recovered psychometric function would be 3 deg/s. PSEs above 3 deg/s indicate some contribution of the retinal information. For all (N=3) observers, PSEs were considerably greater than 3 deg/s and, assuming a linear combination rule, the associated estimated weights for R were between 25% and 49%.We conclude that visual self movement information is involved in the estimation of object movement, even when extra-retinal information is present.

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23.538 **Non-informative components of retinal and extra-retinal signals affect perceived surface orientation from optic flow**

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We test two predictions of a new computational model for the interpretation of the Optic Flow (OF) (Domini, et al., VSS 2012): (1) perceived orientation of a planar surface rotating about an axis coplanar to the surface undergoes a 90° flip whenever a translational component orthogonal to the axis of rotation is added to the OF; (2) the perceptual interpretation of the OF relies on the angular, but not on the linear component of observer's egomotion. In Experiment 1, a static observer viewed the OF produced by a random-dot planar surface rotating about a vertical axis (e.g., a rigid flag hinging on a vertical pole). This OF induces a veridical perception of the surface orientation. However, consistently with prediction (1), when a vertical translational component was added to this OF, the 3D interpretation underwent a 90° flip (i.e., a rigid flag hinging on a horizontal pole). In Experiment 2, the OFs were actively produced by observer's head movements. The observer looked at rotating planar surfaces while performing either a lateral translation of the head or a horizontal head rotation (yaw). In one condition the motion of the planar surface was tethered to the motion of the observer, so that the translational component of the OF was nil. In another condition a surface rotating about a static axis of rotation produced the same lateral translation of the OF tested in Experiment 1. Consistently with prediction (2), perceived surface orientation depended on the lateral motion of the OF in the head-translation, but not in the in the head-rotation condition. Experimental results support the model proposed by Domini, et al., (VSS 2012).

23.539 **The Structure of Optical Flow for Figure-Ground Segregation**

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Introduction: Patterns of accretion and deletion of visual structure are indicative of ordinal depth structure along motion boundaries [Gibson et al., Perception & Psychophysics 5, 1969]. We propose a neurally inspired model that derives ordinal depth order by analyzing spatio-temporal configurations of optic flow patterns at and the motion of kinetic boundaries. Method: A neural model architecture is proposed that detects and spatially integrates motion signals in accordance with cortical stages V1 and MT. Changes in flow pattern characteristics (flow discontinuities or speed and direction changes) are detected in model MST using a mechanism to signal boundary orientations. Furthermore, we suggest that neural mechanisms exist that are sensitive to register secondary motion features, ie. that of moving kinetic boundaries. Activity of such kinetic boundary movement in combination with signals from model MST are used to generate border ownership signals which can be interpreted as likelihoods of a contour that belongs to a surface in a certain direction. An integration process operating at lower spatial resolution provides feedback to the border ownership signal and allows Gestalt-like grouping of boundary pairs with opposite ownership direction tags. Results: We probed our model with various artificial scenes and with a benchmark consisting of real-world sequences [Stein & Hebert, IJCV 82, 2009]. The model generates stable border ownership signals from interactions of the hierarchical stages of the model. We particularly demonstrate that inconsistencies in the movement of kinetic boundaries compared to the surrounding (discontinuous) flow pattern lead to perceptual ambiguities. Conclusion: Our proposed model shows that local depth structure can be computed by local neural mechanisms in a distributed fashion. We show that local estimation of motion gradient and movement of kinetic boundaries is sufficient to estimate ordinal depth structure.

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23.540 **Children's cortical responses to optic flow patterns show differential tuning by pattern type, speed, scalp location and age group**

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Optic flow provides an individual with information about her speed and direction of self-motion (Britten, 2008; Gibson, 1950). Radial (expansion/contraction) optic flow patterns elicit robust evoked potential responses in adults, while responses to rotation and translation (left/right) patterns

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are weaker. Comparatively, infants show the strongest evoked responses to lateral translation (Gilmore et al., 2007). Adult-like spatial and temporal tuning to global motion develops over a prolonged time period (Kiorpes & Movshon, 2004; Hou et al., 2009). For this study, we recorded steady-state visual evoked potential (SSVEP) responses among children of 4 to 8-years to coherence modulations of three optic flow pattern types (lateral translation, rotation, and radial expansion/contraction) at 3 different speeds (2, 4, and 8 deg/s), using an electrode net of 128 channels. Children (n= 20) viewed moving dot displays (7 amin dots, 79.4 cd/m2, density = 10%) that modulated in time from incoherent to 100% coherent global motion at 1.2 Hz (F1). All displays had the same dot update rate (24 Hz, F2). As a group, children's responses to coherence modulation were largest for the radial patterns with peak responses observed over medial occipital electrodes. However, individual age groups displayed differential tuning. Four-year-olds showed the most robust responses to translation over the lateral occipital electrodes while 5-year-olds showed the strongest responses to translation and radial patterns. Six and 7-year-olds displayed strong responses to radial and rotation patterns. Finally, 8-year-olds displayed weak responses to translation and rotation, but strong responses to radial motion over medial occipital channels. Overall, speed tuning varied by pattern type, scalp location, and age group. The results suggest that adult-like sensitivity to optic flow patterns emerges in middle childhood, that optic flow engages a network of visually sensitive areas, and that there are multiple trajectories associated with the development of optic flow processing.

23.541 **Visual perception of object motion during self-motion is not accurate**

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Recent studies have suggested that the visual system subtracts the optic flow pattern experienced during self-motion from the projected retinal motion of the environment to recover object motion, a phenomenon called "flow parsing". Here we investigated the extent to which the visual system accurately performs flow parsing. Two displays (83°x83°, 500ms) simulated an observer either approaching a frontal plane or translating over a ground plane providing motion parallax and static depth cues while a probe dot moved over these planes. For both displays, a vertical component (along the world Y-axis) under control of an adaptive staircase was added to the probe dot's horizontal motion on the plane to determine when the probe motion was perceived as horizontal. The mid-point of the probe's motion trajectory was either 2° or 4° below the focus of expansion of the flow pattern, which was fixated. If flow parsing were complete, no vertical component would be needed as truly horizontal motion on the plane would be perceived as horizontal. Instead, for all 6 participants an upward motion component was needed for the probe to perceptually move horizontally. The magnitude of this upward motion component was consistent with only 64%±4% (mean±SE) of the optic flow being subtracted at 4° eccentricity and 72%±5% at 2° eccentricity for the frontal plane condition, and 71%±3% and 81%±2% being subtracted at 4° and 2° eccentricities for the ground plane condition. For the frontal plane stimulus with a probe moving on the image plane, a condition used by Warren & Rushton (2009), only 52%±4% and 57%±4% of the optic flow was subtracted at 4° and 2° eccentricities. We conclude that while static depth cues help flow parsing for the perception of object motion during self-motion, using a purely visual strategy may not be sufficient to explain our accurate perception of object motion during self-motion.

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23.542 **Patterns of optic flow experienced by infants and their mothers during locomotion**

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Understanding the emergence of mature motion processing requires knowledge about the statistics of the visual input that infants and adults are exposed to and how these change across development. Here we study the optic flow experienced by infants and their mothers during locomotion. Methods. We analyzed head-centered optic flow from (N=6) mother/infant dyads who both wore head-mounted eye trackers that provided a scene camera video stream at 30 Hz. Optic flow was estimated from these videos and fed into a neural model of flow pattern sensitivity for three categories: Expansion/contraction, laminar, and clockwise/counterclockwise (Duffy & Wurtz, 2001). Spectra of the occurrence of these patterns were computed. Results. Pooled over all 12 subjects 27% of the frames contain expansion flow, 3% backward flow, 15% clockwise, 14% counterclockwise, and 41% laminar flow. Five infants show a frequency of laminar flow around 1.5 Hz. Four mothers show the same frequency in laminar flow; however, with a larger spread around 1.5 Hz. In 5/6 cases, flow velocities are higher in videos from infants than those from mothers. But, we did not find substantial differences in the distribution of flow patterns between infants and their mothers. Conclusion. Flows experienced by infants in passive locomotion and the adults who are carrying them are similar, including temporal oscillations near 1.5 Hz that may be related to the mother's gait cycle shared by infants. Most infants experience higher flow speeds than adults perhaps due to reduced stability of the head. Future work will examine retinal flow speeds.

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23.543 **Visual Processing of Impending Collision: Differential Processing of Object Motion and Self-motion**

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As an object approaches an observer's eye, the optical variable tau, defined as the inverse relative expansion rate of the object's image on the retina (D. N. Lee, 1976), approximates the time to collision (TTC). Many studies including our own (Yan, et al, JoV, 2011) have provided support for the tau strategy. The initial proposal for the use of tau in visual motor control assumed that the type of visual motion was irrelevant (i.e., whether the object is moving towards an observer or an observer is moving towards the object). In the present study, we investigated the use of tau during self-motion and compare it to optically comparable situations of object motion. When approaching a stationary object during self-motion, the retinal image of the object will expand on the retina while at the same time the retinal image of the background behind the object will also expand, although at a lesser rate. i.e., the expansion of the object image in relative term compared to an expanding background is smaller than the expansion of the same object against a stationary background. Through three experiments, we demonstrated that that during forward self-motion, observers overestimated TTC compared to situations of equivalent object motion and such overestimations were likely contributed by the use of relative expansion of the target against the expanding background. The overestimation was seen in relative TTC judgement task (discriminating TTCs of two movements) but not on absolute TTC judgment task (estimating the magnitude of TTC of one movement). The importance of relative 3D motion signal found here is consistent with the well-known phenomenon in which relative motion in a 2-dimensional plane between the object and background is known to be processed at neural and behavioural levels. The results provide important insight into the critical visual features in target directed movement.

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23.544 **Time-Variable Motion Parallax Cues**

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Depth perception from motion parallax due to lateral observer translation with fixation uses both retinal image motion and the extra-retinal smooth pursuit signal. When distractor objects are in line-of-sight with the fixate, the relative depth from the fixate is mathematically determined by the ratio of the rate of retinal motion over the tracking rate. When distractor objects are off to the side of line-of-sight, this ratio does not give a good prediction, but the ratio is a time-varying quantity as is the position relative to line-of-sight. In (Stroyan & Nawrot, 2011, J. Math. Biol.) we showed that the motion/pursuit ratio reaches a maximum value at a position where the fixate and a particular distractor are more, but not exactly, in line. We also showed that the peak ratio can be used to build a point-by-point approximation of the structure of an object. We show here that the peak ratio for a particular distractor point occurs at the same physical location where the ego-centric relative depth reaches a maximum. This gives a simple expla-

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nation of why the peak is not exactly in line-of-sight and why each peak is determined at the same observer position for different translation speeds. Old experiments (Hildreth, et al, 1990, Perception & Psychophysics, Eby, 1992, Perception & Psychophysics) observed integration times necessary for depth perception an order of magnitude greater than our more recent results. We show how the peak motion/pursuit time could be the cause of this difference for a complicated stimulus shape.

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23.545 **Effect of image size on speed estimation for real world moving scenes**

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Perceived motion is usually consistent with image shift on the retina when self motion (eye/head etc) is eliminated. However, when estimating the actual speed of an object in the real world, observers may use other information in addition to motion signals. We investigated the effect of image size on driving speed estimation based on real-world videos. In our study we manipulated motion signals through selection of 84 driving video clips (taken from the driver's perspective), with driving speeds ranging from 5 to 60 mph at 5-mph intervals. Each clip was 5-second long, and shown in one of 4 image sizes (44º, 33º, 21º and 16º wide, aspect ratio 0.38 to 1). Nine subjects each viewed the sequence of video clips, including all combinations of size and driving speed, in a random order, and then reported estimated driving speed. For each subject and each image size, the dependence of speed estimation on actual driving speed was described through linear regression. The slopes (mean 0.84) of the regression lines were not significantly different across image size ($F(3,8)=2.69$, $p=0.074$), and neither were the offsets (mean 5.25) of the regression lines significantly different ($F(3,8)=2.24$, $p=0.11$). The middle speed range (25–40 mph) was more accurately estimated than the lower (5-20 mph) and higher (45-60 mph) speed ranges. The mean errors in each speed range were 4.07±6.47(SD) mph for the lower range (overestimate), 0.23±4.99 mph for the middle range, and -2.57±6.32 mph for the higher range (underestimate). As we did not find any effect of image size on driving speed estimation, our results suggest that observers can calibrate their estimation of driving speed for the image scale, possibly by using reference and experience. Keywords: Speed perception; Image scale; Optic flow

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23.546 **Less ecologically valid optic flow causes more postural sway**

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When we move through our environment we experience optic flow. Flow patterns typically contain a wide range of velocities. Radial optic flow patterns consisting of random dots, moving at a single speed, become less ecologically valid. Here we investigate to what extent ecological validity is a prerequisite for the experience of vection. As measure we use the amount of postural sway resulting from different types of expanding or contracting optic flow. We varied the validity of 3 radial optic flow types by manipulating their velocity profile (quadratic-speed gradient (Q), linear-speed gradient (L), single-speed (S)), assuming decreasing ecological validity. Four single-speed optic flow velocities were presented (6, 12, 24 or 48 deg/s), while in speed-gradient stimuli these velocities corresponded to half the integral of their speed-gradient curve. Stimuli (radius 43.5°, duration 4s) were presented in pseudo-random order, interleaved by dynamic visual noise patterns (duration randomly varied between 3.4-4.2s). Participants stood on a force-plate in a completely dark room. The effect of each optic flow stimulus was determined by calculating the postural sway on the anterior-posterior axis. In general we find that higher flow velocities lead to more postural sway. Interestingly, most sway was observed for the assumed less ecologically valid conditions. In addition, we find an anisotropy in that (QLS) contracting stimuli generate more sway than expanding stimuli. Specifically, for contracting optic flow the largest effect was found for the single-speed conditions, although all QLS stimuli resulted in significant sway. In contrast, for expanding optic flow, only the single-speed conditions resulted in significant sway. This study indicates that the experience of vection as measured by body sway is strongest for contracting, ecologically less valid optic flow. This might be explained by interactions between our visual and sensorimotor systems that are tailored towards compensating for ecologically valid stimuli.

23.547 **Long-range relationship between separated local motion signals is rapidly encoded in a point-to-point manner.**

Kazushi Maruya[1], Shin'ya Nishida[1]; [1]NTT communication science laboratories

Synchrony provides critical information for perceiving spatiotemporal structures from parallel inputs. Human ability of synchrony-based feature binding can be accessed by asking observers to judge which features occur at the same time across two repeatedly changing stimuli in separate locations. In case of motion direction, the upper limit (critical temporal frequency) for this judgment is fairly high (~12 Hz) regardless of the spatial separation of compared local motions at least up to 100 deg (Maruya et al., VSS2010). This finding suggests that the long-range relationship between local motions may be rapidly encoded by special hardware. However, one might suspect that this hardware is not a novel mechanism, but what is already known as optic flow detectors, since most of the local-motion relationships that show rapid binding performance (e.g., up on the right and down on the left) are included in global rotation, expansion or translation. The critical difference between the two hypotheses is the range of spatial pooling. While we propose a mechanism that monitors only task relevant locations, optic flow detectors will respond to any relevant local motions presented in their large receptive field. To estimate the pooling range of the underlying mechanism, we measured the critical temporal frequency for a pair of vertically moving elements (targets) under concurrent presentation of masker elements. These maskers were designed to disturb the global rotation detector that could assist the task. Therefore, if the global rotation detector is indeed responsible, the critical frequency should significantly fall off by these maskers even when the separation from the targets was increased. However, the results showed that the magnitude of the masking effect gradually decreased as a function of the target-masker distance. These results are consistent more with local motion comparison in a point-to-point manner, than with global rotation detection.

23.548 **Motion parallax, pursuit eye movements and the assumption of stationarity**

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Background: Rogers and Gyani (Perception 39, 2010) showed that the parallax transformations created by observer movement can only specify depth order and magnitude unambiguously if it can be assumed that the 3-D structure remains stationary during the observer movement. Using virtual 'Reverspectives', we have shown previously that the visual system makes no such assumption, at least when there is conflicting perspective, shading or disparity information (Rogers, B J. J Vis 10(7), 2010). The present experiment was designed to test whether the absence of rotation - stationarity - is assumed, or has to be specified, when motion parallax is the only source of 3-D information. Methods: To do this, observers viewed parallax transformations specifying a horizontally-oriented, sinusoidal corrugated surface while they made side-to-side head movements. Results: When there was vertical perspective (Braunstein M. and Payne J, JOSA 58 1968) and foreground flow information to specify the observer's rotation with respect to the surface, depth order was unambiguous and seen correctly. In the absence of these cues, the depth order was often seen incorrectly such that the reversed-depth corrugations appeared to rotate with the observer (but at twice the rate), as seen in the hollow mask illusion. In a second experiment, observers viewed a display that recreated all of the features of the optic flow that would normally be created during side-to-side head movements, but the observer did not move, gaze was fixed and hence no pursuit eye movements were necessary or evoked. Under these conditions, the perceived depth order was stable and unambiguous. Conclusions: (i) stationarity is not assumed by the visual system but has to be specified and (ii) pursuit eye movements (Nawrot, M. Vision Research 43, 2003) are neither necessary nor sufficient to disambiguate depth order.

23.549 **The effect of monocular depth cues on the detection of moving objects by a moving observer**

Constance Royden[1](croyden@mathcs.holycross.edu), Daniel Parsons[1], Joshua Travatello[1]; [1]Department of Mathematics and Computer Science, College of the Holy Cross

As observers move through the environment, they must detect moving objects. Previously, we showed that observers can use 2D image speed to detect moving objects in the radial optic flow field generated by a moving observer. However, a difference in image speed may signal either a moving object or a depth difference between stationary objects. Adding depth information may remove this ambiguity. We tested observers' ability to detect a moving object in scenes that contained increasingly salient monocular depth cues. We simulated observer motion in a straight line at a speed of 3 m/sec toward a scene that consisted of a textured ground plane with 8 objects located 12 m from the observer. In two conditions the objects were featureless red disks (diameter: 0.4 m) located on the horizontal midline that were either separate from the ground plane (condition 1) or connected to it with a thin line, giving a cue to distance (condition 2). In condition 3, the objects were textured blocks (width: 0.55 m; height: 1.6 m) located on the ground plane, giving further cues to depth. In half the trials one object moved faster (or slower) than the other objects in the scene. The speed differences ranged from 10% to 100% of the image speed of non-targets. Each trial lasted 1 sec. Observers indicated with a key press whether or not the scene contained a moving object. Thresholds were computed by fitting the data with a sigmoidal curve and determining the percent speed difference that led to 75% accuracy. For the 6 subjects tested, the results show a significant effect of scene condition, with average threshold speed changes of 43%, 37% and 25% for conditions 1, 2 and 3, respectively. Thus, monocular depth cues aid the detection of moving objects by moving observers.

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Attention: Temporal

Saturday, May 12, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

23.551 How the attentional blink interacts with the object-based attention?

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The present study investigated how the attentional blink (AB) interacts with the object-based attention by presenting four RSVP streams on four ends of two rectangles, to ask a question that T2 performance would benefit (e.g. Egly, Driver, & Rafal, 1994) or suffer (Conci & Müller, 2009) from its occurrence on the same object as T1. Essentially replicating the paradigm of Conci and Müller (2009), a same-object cost within the AB period (lag 3) was replicated in Experiment 1 in which the background rectangles and RSVP streams were presented at the same time. However, either longer interval (1 second) between the onsets of rectangles and RSVP streams (Experiments 2) or lower task demand of searching among four replicated letters within each frame of RSVP displays before T1 (Experiment 3) produced a same-object advantage within the AB period (lag 3). Experiment 4 presented T1 on the early (2nd or 3rd) and late (13th or 14th) temporal positions in a random order, and also at lag 3, obtained a same-object cost with early T1 positions, and a same-object advantage with late T1 positions. According to these results, we proposed that, if the operation of opening object file and T1 processing are overlapping, this overlap of two resources-consuming processes would deteriorate the depletion of resources within the same object, resulting in a same object cost in the AB; however, if the object file is well established before T1 processing, T1 could serve as a cue to facilitate T2 performance within the same object, resulting in a same object advantage in the AB. This study extended our view of the AB across objects, and provided theoretical implications concerning the limited-capacity of human brain.

Acknowledgement: This study was supported by grants from the Natural Science Foundation of China (30970893).

23.552 Visual entrained attention is not location specific, but it is voluntary.

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Martin et al. (2005) demonstrated that visual attention could be entrained to temporal structure much like auditory attention, but their design confounded choice reaction and go-no go processes, clouding the interpretation of the benefit to entrained attention. Design improvements corrected the confound and revealed a reduced but still significant reaction time benefit of entrained visual attention. In two new experiments, flashes of light counted down to a target that required a choice reaction. Reaction time and accuracy were measured. Accuracy was uniformly high. Manipulations of target location relative to cue location revealed no evidence of location specificity at entrainment to 2 Hz. There was a benefit to reaction time whether the target occurred at the same visual field location as the cue or a different location. There was limited location specificity of entrainment to 1 Hz. The benefit of entrainment was present but reduced when the target was at a different visual field location than the cue. Manipulation of timing to make the cue uninformative reduced the benefit to the expected pattern of a simple warning stimulus paradigm, indicating that when the cue was uninformative participants either did not entrain visual attention or ignored the entrained process.

23.553 Effects of stimulus energy on the attentional blink

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Perception of the second of two targets (T2) embedded in a temporal stream of distractors is often impaired as compared with perception of the first target (T1), a phenomenon known as the attentional blink (AB). Explanations of the AB commonly ascribe the impairment to a conflict in postperceptual stages of processing. Here, the standard AB paradigm was manipulated to investigate the effect of the stimulus energy (the absolute value of the product of contrast and exposure duration) of the individual items (alphanumeric characters) in the rapid serial visual presentation (RSVP). In both experiments, all items in the RSVP were presented with a constant stimulus-onset asynchrony of 100 ms. In Experiment 1, the items were presented in black on a white background, and the duration of individual stimuli was either 30 ms (corresponding to an interstimulus interval of 70 ms) or 100 ms (corresponding to an ISI of 0 ms). In Experiment 2, the stimulus duration was kept constant at a value of 100 ms with zero ISI, but the luminance contrast of the stimulus items was varied between conditions (black on white vs. dark grey on light grey). In both experiments, the results showed strong effects of stimulus energy. T2 report accuracy showed superior performance in high-energy conditions (long exposure duration in Experiment 1 and high contrast in Experiment 2) compared with low-energy conditions (short exposure duration and low contrast). Additionally, calculations of blink magnitude using T1 report accuracy as baseline performance revealed a stronger blink in low-energy conditions compared with high-energy conditions. Thus, although most theories place the locus of the AB at a late stage of processing (e.g., consolidation in memory), mechanisms of early vision also contribute to the effect.

23.554 Detecting to the beat of your own drum: the phase of low-delta oscillations leads a subject-specific mix of higher frequencies in the determination of visual-target detection

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Our own work, as well as that of others, has demonstrated the oscillatory nature of visual perception. For example, the phase of ongoing cortical oscillations influences the likelihood of visual-target detection, such that a near-threshold stimulus is more likely to be detected if it occurs during a high-excitability state. Debate persists, however, regarding which specific frequencies influence visual-target detection. Some recent studies have demonstrated phase-behavior relationships at theta and alpha frequencies (5–14 Hz); other studies, which focused on the interaction between attention and visual-target detection, have instead emphasized the importance of low-delta (1–2 Hz) frequencies. Here, we recorded high-density EEG during a visual sustained-attention task to investigate phase-behavior relationships across a broad range of frequencies (1–50 Hz). We further endeavored to examine inter-subject differences in the frequencies that underlie behavioral performance. Subjects responded whenever they detected a near-threshold visual stimulus, which either co-occurred with an auditory cue or anytime up to 5 seconds thereafter. Our data reveal that the prestimulus oscillation most consistently linked with detection across subjects had a frequency of approximately 1 Hz. Detection was also significantly linked to the phase of oscillations at higher frequencies (e.g., theta and alpha), but the specific frequencies of these other phase-behavior relationships varied substantially across subjects. A closer examination of the data further revealed that the phase-behavior relationship at higher frequencies was sometimes mediated by phase-power coupling with the 1-Hz oscillation. That is, power at higher frequencies was dependent on phase of the 1-Hz oscillation. Binning trials

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based on the phase of the 1-Hz oscillation revealed a stronger phase-behavior relationship at higher frequencies. Overall, our results shed light on the complex interplay between visual perception and oscillatory activity on different temporal scales. We further demonstrate that the specific frequencies linked to visual-target detection vary on a subject-by-subject basis.

23.555 **Attentional rhythm: A temporal analogue of object-based attention**

Julian De Freitas[1](julian.defreitas@yale.edu), Brandon M. Liverence[1], Brian Scholl[1]; [1]Dept. of Psychology, Yale University

A critical step in understanding any perceptual process is determining the underlying units over which it operates. For example, decades of research have demonstrated that the underlying units of visual attention are often visual objects. This conclusion has been supported by the demonstration of a 'same-object advantage': for example, nonpredictive cues lead to faster target responses when cue and target both occur on the same object versus when they occur on distinct objects, equating for spatial distance. Such effects have been well characterized in the context of spatial attention, but to our knowledge no previous studies have investigated the possibility of analogous effects for temporal attention. Here we explore whether a particular class of temporally-extended auditory "objects" — rhythmic phrases — might similarly serve as units of temporal attention. Participants listened to a repeating sequence of rhythmic phrases (3-4 seconds each) of a low-pitch tone while trying to quickly detect sporadic higher-pitch target tones, each of which was preceded by a fully-predictive cue tone. While equating for the brute duration of the cue-target interval, some cue-target pairs occurred within the same rhythmic phrase, while others spanned a boundary between phrases. We observed a significant "same-phrase" advantage: participants responded more quickly to Within-Phrase than Between-Phrase targets. These results reveal a new phenomenon of temporal attention, as well as a new analogue between visual and auditory processing. In particular, they suggest a more general interpretation of typical object-based effects in visual attention: just as the structure of a scene will constrain the allocation of attention in space, so too might the structure of a sequence constrain the allocation of attention in time. Thus, rather than being driven by particular visual cues, per se, "object-based attention" may reflect a more general influence of perceived structure of any kind on attention.

23.556 **The long life of conspicuity: bottom-up factors play a role beyond the initial saccade.**

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Many models of selection in visual search predict saccades to be biased towards conspicuous objects (often referred to as salient). In accordance, it has been demonstrated that initial saccades are indeed biased towards the most conspicuous element. Yet, only few studies have explicitly investigated how elements of different conspicuity affect scanning order beyond the initial saccade. One recent study (Siebold, Van Zoest & Donk, 2011) does investigate whether the saccade following the first is biased towards the most conspicuous of the potential candidates for the second saccade. Despite conspicuity differences between these candidates, no bias towards the most conspicuous candidate was found for the second saccade. Upon this finding they conclude that selection beyond the initial saccade is primarily under top-down control. However, this conclusion, which contrasts with many influential models of selection, is based on only a single conspicuity manipulation (three deviating orientations on a grid of vertical nontargets). Here we investigate whether their finding can indeed be generalized by introducing luminance variations to create conspicuous locations. In our experiment, three annuli of varying luminance were placed around a vertical target and two horizontal distractors to introduce differences in conspicuity. Observers were asked to find the vertical target as quickly as possible and were informed that luminance differences between the annuli were not predictive of the target's location. In contrast to the findings of Siebold et al. we do find a large bias towards the most conspicuous candidate for the second saccade. This bias is present even for the longer inter-saccade intervals. Thus, bottom-up factors can still play a role in eye movements beyond the initial saccade. Whether second saccades are biased towards more conspicuous elements appears to depend on the type of contrast underlying the conspicuity.

23.557 **Effect of lateralization of emotional faces and letters on the attentional blink.**

Marcia Grabowecky[1](grabowecky@northwestern.edu), Laura Ortega[1], Chika Nwosu[1], Satoru Suzuki[1]; [1]Department of Psychology, Northwestern University

Emotional events attract and capture attention. A particularly salient stimulus is an emotional face. Faces, emotional or non-emotional, are preferentially processed in the right hemisphere. We used a lateralized attentional blink paradigm to investigate whether presentation of emotional faces to the left or right hemisphere differed in the magnitude of attentional blink. Targets were three different male faces expressing neutral, happy or angry expressions. On each trial, two upright targets (a neutral and an emotional face or two neutral faces) were presented within a stream of inverted-face distractors that were selected from a different set of neutral faces. As a control, we ran a second group that performed a lateralized version of a standard attentional blink task with upright letters as targets and inverted letters as distractors. We hypothesized that emotional faces might be preferentially processed in the right hemisphere, whereas letters, as linguistic stimuli, might be preferentially processed in the left hemisphere. Stimuli for both tasks were presented on the left or the right of the display centered at 3.72^o from a central fixation point. Participants were pre-cued about the stimulus location and we verified fixation throughout each trial with an eye-tracker, terminating any trial where the eyes deviated vertically or horizontally by more than 2.14^o from the fixation point. The magnitude of the attentional blink was reduced for left-visual-field/right hemisphere presentations (LVF/RH) for both neutral faces and letter stimuli, suggesting that the observed reduction in attentional blink magnitude for the LVF/RH was not due to a right hemisphere specialization for faces. It is possible that the right hemisphere is generally better at discriminating upright from inverted stimuli than is the left hemisphere or perhaps the right hemisphere is in general better at processing rapid stimuli.

23.558 **Detecting temporal misorderings requires more effort than detecting the misordered actions**

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Previous research has emphasized the importance of automatic prediction and error detection in event perception (e.g., Zacks 2007). However, we have previously demonstrated that individuals have difficulty detecting out-of-order actions embedded within familiar events, calling into question the use of moment-to-moment predictions in understanding these events. In this experiment, we tested whether detecting misorderings is especially dependent on effortful processing by investigating the effects of an interfering task on both the ability to detect misordered actions and to detect the presence of a previously viewed action. Participants watched videos (consisting of a series of eight to fourteen different shots, with each shot lasting an average of 820 ms) of actors performing everyday activities that either did or did not contain a misordered action (for example, a shot of an object being used before a shot of it being picked up). Half of the participants were instructed to look for misorderings. The other half viewed a clip of an action immediately before each video, and were instructed to press a key when they saw the action appear in the subsequent video. For trials with misordered events, this action was always out of order. Additionally, all participants were instructed to engage in a verbal counting task for half the trials. When instructed to look for misorderings, the interference task significantly lowered detection of misordered events without increasing false alarm rates. The interference task, however, did not lessen the detection of clips within misordered videos. Interestingly, even though participants were able to successfully identify the target clip, which was misordered in half the trials, incidental detection of the misordering itself was very rare. These results suggest that sequence prediction and error detection requires substantial cognitive effort.

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23.559 **Performance on Multiple Different Global/Local Processing Measures Predict Individual Differences in the Attentional Blink**

Gillian Dale[1](gd03fh@brocku.ca), Karen M. Arnell[1]; [1]Department of Psychology, Brock University

When the second of two targets (T2) is presented temporally close (within 500ms) to the first target (T1), accuracy for identifying/detecting T2 is markedly diminished -- an attentional blink (AB). Using Navon letter stim-

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uli, Dale and Arnell (2010) demonstrated that individual differences in dispositional attentional focus (i.e. global or local) were associated with performance on the AB task, such that individuals who focused more on the local level information were more susceptible to the AB. The purpose of the current study was to extend this finding by using three different measures of global/local processing to predict AB performance. In the first global/local task, participants viewed congruent or incongruent Navon letters, and were asked to attend to the local or global level so that global and local interference could be estimated. For the second task, participants viewed incongruent hierarchical shapes (e.g., a square made of triangles), and then made a forced-choice decision about which of two shapes best matched the hierarchical shape. For the third task, participants viewed superimposed faces containing the high spatial frequency information of one individual and the low spatial frequency of another individual. They then indicated which of two intact faces had been presented as the hybrid. Participants also completed a standard AB task. As hypothesized, performance on all three global/local tasks predicted subsequent AB performance, such that individuals with a greater preference for the global (low spatial frequency) information showed a reduced AB. However, a regression analysis revealed that while performance on all three global/local tasks predicted the AB, they all predicted unique variance in AB magnitude. This suggests that if indeed these global/local tasks are measuring some aspect of global/local processing, they are all measuring unique, rather than similar, processes.

Acknowledgement: NSERC, CFI, OIT

23.560 **Resting EEG in alpha and beta bands predicts individual differences in attentional blink magnitude**

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[1]Brock University

Accuracy for a second target is reduced when it is presented within 500 ms of a first target in a rapid serial visual presentation – an attentional blink (AB). There are reliable individual differences in the magnitude of the deficit observed in the AB. Recent evidence has shown that the attentional mode that an individual typically adopts during a task or in anticipation of a task, as indicated by various measures, predicts individual differences in the AB. It has yet to be observed whether indices of attentional mode when not engaged in a goal-directed task are also relevant to individual differences in the AB. Using an individual differences approach, we investigated the relationship between the AB and attention at rest as assessed with quantitative measures of EEG. Greater levels of alpha at rest, thought to represent an idling or inhibited cortex, were associated with larger AB magnitudes, where greater levels of beta at rest were associated with smaller AB magnitudes. Furthermore, individuals with more alpha than beta at rest demonstrated larger AB magnitudes than individuals with more beta than alpha at rest. This pattern of results was observed in two different studies, with different samples, different AB tasks, and using different procedures and recording systems. Our results suggest that less attentional engagement at rest, when not engaged in a goal-directed task, is associated with larger AB magnitudes. It is possible that high levels of alpha and low levels of beta at rest are representative of an internally oriented mode of attention that impairs perception of externally generated information as is required by the AB task. An alternative hypothesis is that high levels of alpha and low levels of beta at rest are representative of an anticipatory mode of attention that results in detrimental overinvestment in the AB task.

Acknowledgement: NSERC, CFI, OIT

Visual search: Eye movements and models

Saturday, May 12, 2:30 - 4:15 pm
Talk Session, Royal Palm Ballroom 1-3
Moderator: Ignace Hooge

24.11, *2:30 pm*
Ineffective visual search: Search performance deteriorates near borders due to inappropriate fixation durations and saccade amplitudes.

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When searching, people usually scan the visual field by making saccades. From the literature we know that saccade amplitude and fixation duration are related to the amount of information to be processed during fixations. Contrast borders may affect target detectability due to lateral masking. We hypothesize that the oculomotor system uses both target-background and search area border information to adjust fixation duration and saccade amplitude, enabling search to be effective. To test the effect of the border of the search area we designed a search stimulus in which border contrast was varied to manipulate the difficulty of the search task. Target-background contrast was kept constant. The stimulus was a target (a barely visible light gray dot) placed in a further empty search area (a randomly oriented homogenously gray triangle). The target was present in 50% of the trials. Question: How does border contrast affect search performance and saccade behavior? Results. Percentage correct was lowest en reaction times were longest for search areas having borders of high contrast. This result indicates that high-contrast borders mask stronger than low-contrast borders. The majority of the errors were misses. Fixation density was highest near borders. Surprisingly, high fixation density was not associated with small saccades amplitudes. Near borders, saccades were large and mainly directed in parallel with the borders. High fixation densities near borders were mainly caused by re-inspections. Fixation time was nearly constant over the search area. Apparently, the oculomotor system does not adjust fixation duration and saccade amplitude to compensate for increased search task difficulty near borders, resulting in lower search performance (missed targets).

24.12, *2:45 pm*
Searching for objects in a virtual apartment: the effect of experience on scene memory

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How do we form memories for real-world environments over time and how do these memories influence gaze behavior? There is considerable evidence that humans develop fairly extensive, often implicit, memory representations of natural scenes. Most investigations of memory for natural environments, however, have used static 2D images often involving the presentation of multiple unrelated scenes. In contrast, natural experience entails immersion in a limited number of 3D environments for extended periods of time, which may facilitate the build up of more extensive memory representations. To investigate scene memory development in natural settings, we recorded the sequences of saccades and body movements while observers searched for and touched a series of different objects in a 3-room virtual apartment, over 30-minute periods on two consecutive days. Subjects rapidly learnt the global layout of the apartment and restricted gaze largely to regions where surfaces, e.g. counters, were located. For objects that appeared as search targets on repeated occasions, both search time and number of fixations diminished gradually over repeated search episodes (by factors of 3 and 2, respectively). Thus, the binding of particular objects to particular locations is learnt fairly slowly, despite the presence of a constant context. Surprisingly, learning appeared to require active search. When an object first became a search target there was no measurable reduction in the amount of time or number of fixations required to locate it, even if it had been spontaneously fixated upon multiple times (~40) while the subject was searching for other objects. This lack of passive learning may be a consequence of the highly task-specific processing that occurs when engaged in search, which might suppress the encoding of task-irrelevant distracters. Thus, visual search in natural environments appears to be largely guided by memory representations that are dependent upon task-directed attentional constraints.

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24.13, *3:00 pm*
Inhibition of gaze promotes exploration and search of natural scenes

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Active exploration of the visual world depends on sequential shifts of gaze that bring prioritized regions of a scene into central vision. The efficiency of this system is commonly attributed to a mechanism of "inhibition of return" (IOR) that discourages re-examination of previously-visited locations. Such a process is fundamental to computational models of attentional selection and paralleled by neurophysiological observations of inhibition of target-related activity in visuomotor areas. However, studies examining eye movements in naturalistic visual scenes appear to contradict the hypothesis that IOR promotes exploration. Instead, these reports reveal a surprisingly strong tendency to shift gaze back to the previously fixated location – suggesting that refixations might even be facilitated under natural conditions. Here we resolve this apparent contradiction, based on a probabilistic analysis of gaze patterns recorded during both free-viewing and search of naturalistic scenes. By simulating saccadic selection based on instantaneous influences alone, we show that the observed frequency of return saccades is in fact substantially less than predicted for a memoryless system – demonstrating that refixation is actively inhibited under natural viewing conditions. Furthermore, these observations reveal that memory for gaze history significantly influences the way in which natural scenes are explored, contrary to accounts that suggest visual search has no memory.

Acknowledgement: The Wellcome Trust

24.14, *3:15 pm*
Visual Foraging Behavior: When are the berries riper on the other side of the screen?

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Suppose you are picking raspberries in a field with many bushes, each holding some ripe berries. When do you move to the next bush? You will probably leave the current bush before picking the last ripe berries. The Marginal Value Theorem (MVT, Charnov, 1976) more specifically predicts that you will leave when the current rate of picking drops below the overall rate for the task. Many real world tasks from berry picking to satellite surveillance are foraging search tasks. We have devised a paradigm that creates rich environments for examining human decision making in foraging tasks. Experiment 1: Displays contained 20-30 reddish "berries"; 50% were "ripe". Ripe berries differed from unripe in redness but were drawn from overlapping distributions (D'=2). Observers attempted to maximize ripe berries picked in 15 minutes. They could pick in one patch as long as desired and then move to the next. Ease of picking and travel time between patches varied. Observers picked the ripest berries first and moved when picking got harder. The results conformed well to MVT. Experiment 2: Patches varied from 20% to 80% ripe berries. Overall behavior still conformed to MVT but behavior in single patches did not. Observers stayed too long in lousy patches and left good ones too soon. Quitting rules based on a ripeness/redness threshold worked quite well. Experiment 3 eliminated ripeness information. Patches varied from 20-80% ripe but all berries looked the same. Observers got feedback only after picking each berry. Overall behaviors still conformed to MVT but individual patch behavior

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followed probability matching. Observers picked 20% of the berries in 20% patches and 80% in 80% patches. Obvious quitting rules like moving after N bad berries or N bad berries in a row don't work. MVT describes foraging behavior but does not explain human patch leaving rules.

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24.15, *3:30 pm*

Predicting Performance in Natural Scene Searches

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Completely natural scene search is a paradigm that cannot be directly compared to the typical types of search task studied, where objects are distinct and definable. Here we have look at the possibility of predicting the performance of humans for completely natural scene tasks, using a direct comparison of human performance against new and existing computer models of viewing natural images. For the human task, 25 participants were asked to perform a search task on 120 natural Scenes while sat in a fixed mount eye-tracker. Scenes were 1280 x1024 pixels, viewed at a fixed distance so they covered approximately 37.6o x 30.5o of visual angle. Prior to viewing the Scene, they were shown a 90 pixel (2.7o) square sub-section of the Image for 1s, which was then blanked before the main scene was displayed. In 20% of trials, the presented target was NOT present, and this 20% was balanced across the participants. The identical task was given to a selection of reproductions of existing computer processing techniques, including Feature congestion (Rosenholtz, Li, Mansfield, & Jin, 2005), Saliency (Itti & Koch, 2001), Target Acquisition Model (Zelinsky, 2008) and a new variation on the Visual Difference Predictor (To, Lovell, Troscianko, & Tolhurst, 2008). We show that the models are very bad at generating parameters that predict performance, but that A' of Human performance is predicted pretty well by the simple clutter in the image (r(117) =- .21, p = .017), while a good predictive relationship is found from the new PVDP Cluster Object method we employ (r(58)=-0.37 p=.000). These results lead us to conclude that in natural search tasks, the nature of both the Scene and the Target are important, and that the global influence of local feature groups can have an influence of the task difficulty.

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24.16, *3:45 pm*

Peripheral representation by summary statistics: An alternative to 3-D shape and lighting direction as basic features for search

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Searching for a side-lit shaded cube among top-lit is efficient (~8 ms/item), compared to search using "equivalent" 2-D items (>20 ms/item), or to search for top-lit shaded cubes among side-lit (21 ms/item) (Enns & Rensink, 1990). Arguably these results are puzzling, from the point of view of some theories of search, as they suggest that 3-D shape and direction of illumination might be available preattentively, whereas distinguishing between, say, a 'T' and an 'L' supposedly requires attention. We have argued that the information available in peripheral vision is a key determinant of search difficulty (Rosenholtz et al, in review), and that this information is strongly limited by early representation in terms of summary statistics (Balas et al, 2009). Here we revisit Enns & Rensink's results in light of this rethinking of search. Experiment 1 tests the association between peripheral discriminability and search performance. Observers were asked whether a peripheral item, flanked by 1-4 distractors, was a target or distractor. Experiment 2 tests whether the information available in our hypothesized set of local summary statistics can predict search performance. We extracted a number of target-present and target-absent patches of varying set size (2-5) from search displays. For each one, we synthesized patches with approximately the same summary statistics as the original (Portilla & Simoncelli, 2000). Observers were asked whether each synthesized patch came from a target-present or target-absent original. Conditions corresponded to Enns & Rensink's Experiments 2ABC and 3AB. Statistical discriminability predicts peripheral discriminability (R2=0.77). Both measures predict search difficulty (R2= 0.65 & 0.55), including easier search for 3-D vs. 2-D items, and an asymmetry for lighting direction (though the latter may be an issue of criteria setting rather than a difference in available information). Peripheral representation in terms of summary statistics provides a parsimonious account of search with 3-D vs. 2-D items.

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24.17, *4:00 pm*

Periodic involvement of early visual cortex during attentional visual search: a TMS study

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Visual search is often used to probe the temporal resolution of visual attention. Standard theories posit the involvement of a "saliency map" to select the target position and focus attention. This suggests that during serial (or "difficult") search, there is iterative feedback from the saliency map to lower areas, reflecting the exploration of candidate locations by attention until the target is found. In a previous experiment (Dugué et al., PLOSOne, 2011), we applied double-pulses (25ms interval) of Transcranial Magnetic Stimulation (TMS) over V1 at different delays post-stimulus and demonstrated a specific effect on attentional target selection at 300-325ms. This delay was interpreted as the average delay necessary (in this specific task) to find the target. The aim of this new study is to determine whether V1 is involved at other delays during this task, confirming the presence of iterative feedback between V1 and higher-level areas. We applied double-pulses of TMS (sub-threshold): one pulse fixed at 312.5ms (between 300 and 325ms, see previous experiment) and the second one at variable post-stimulus delays from 112.5 to 437.5ms (25ms steps). Thanks to a phosphene-mapping procedure, the visual stimuli were presented either at the retinotopic location corresponding to the TMS-targeted area, or at the opposite location. Subjects (n=10) performed a serial search task: finding a T among Ls. We simultaneously recorded EEG to relate behavioural results to cortical oscillations. The target detection performance curves revealed a periodic modulation, with TMS-specific impairments recurring at post-stimulus delays compatible with theta frequencies (5.7Hz). EEG results confirmed that the phase of pre-stimulus spontaneous EEG oscillations in the theta frequency range (5-9Hz) covaried with target detection. These results argue in favour of a periodic causal influence of V1 during an attentional search, possibly reflecting successive cycles (~6Hz) of a 'select-and-focus' iterative loop between lower- and higher-level areas.

Acknowledgement: This research was funded by a EURYI award to RV.

Object recognition: Mechanisms and models

Saturday, May 12, 2:30 - 4:15 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Chris Baker

24.21, *2:30 pm*

Image Parsing, From Curves to Natural Images

Danique J.J.D.M. Jeurissen[1](d.jeurissen@nin.knaw.nl), Pieter R. Roelfsema[1,2]; [1]Vision and Cognition Group, Netherlands Institute for Neuroscience, Royal Netherlands Academy of Arts and Sciences, [2]Department of Integrative Neurophysiology, Centre for Neurogenomics and Cognitive Research, VU University

The visual system groups parts of an object together and segments different objects from each other and the background. We challenge the view that grouping is done in parallel and hypothesize that attention spreads over the area of an object to group the object together and to segment it from other objects and the background. We distinguish three models that can explain how the brain achieves perceptual grouping and make a prediction on the time-course of image-segmentation: 1) the eccentricity model, which predicts that the speed of attentional spread depends on the Euclidean distance between points; 2) the pixel-by-pixel model, which predicts that attention spreads at the same speed in all directions within the object; 3) the growth-cone model, which takes into consideration the size of receptive fields in visual areas and predicts that attention spreads faster over homogeneous areas. To test the models, we investigate whether the reaction time (RT) pattern is in accordance with the model prediction for various stimulus sets that vary in their level of complexity. Participants indicate whether two cues are on the same or on two different objects. Eighty-eight participants were randomly assigned to one of the following conditions: natural images, detailed cartoons, cartoon outlines, and scrambled cartoons. Regression analysis of the RT-data shows that the explained variance is highest for the growth-cone model. This demonstrates that attention spreads over the object, thereby serially grouping the different object-parts together and that this attentional spread is faster if it spreads over homogeneous areas of the object and slower on small or narrow part of the object. The superior performance of the growth-cone model is very consistent for the various image conditions, showing that our brain probably uses similar strategies to perceptually group simplified as well as complex objects together into one single object.

24.22, *2:45 pm*

Object Recognition is an Interactive Iterative Process

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Research on object recognition has focused mainly on bottom-up processes that analyze the visual input; the potential role of top-down processes has been relatively neglected. We examined the hypothesis that object recognition is an iterative process in which bottom-up and top-down processes interact to discriminate between alternative object identities, with attention playing a critical role. Although similar ideas have been proposed by others, to our knowledge this is the first attempt to test these ideas empirically. In two experiments observers discriminated between sets of artificial fish. A secondary visual-probe detection task was used to measure changes in the spatial distribution of attention over time. The probe was displayed on 50% of the trials adjacent to a local fish feature for a short duration at several SOAs. In Experiment 1, the fish varied in several local distinguishing features. We assumed that only one feature could be attended at a time and hypothesized that attention would be allocated in the most diagnostic sequence: first to a feature that discriminated between two general classes of fish and then, based on its value, to a second distinguishing feature that would conclusively identify the specific fish. In Experiment 2, fish recognition could be based on either of two distinguishing features, one much more discriminable (perceptually) than the other. On some of the trials, the more discriminable feature was occluded. We hypothesized that attention would be directed initially, by default, to the more discriminable feature, and when this feature was occluded – redirected to the alternative feature. In general, the observed pattern of spatial allocations of attention over time, indicated by probe detection rate at the different locations as a function of SOA, accorded with the predictions, supporting the idea that – when necessary – object recognition is an interactive iterative process in which attention plays a crucial role.

24.23, *3:00 pm* **Holistic object representation in human visual cortex**

Jiedong Zhang[1](zhangjiedong@gmail.com), Yiying Song[1], Jia Liu[1], Yaoda Xu[2]; [1]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, [2]Department of Psychology, Harvard University

Object parts often interact to form holistic representations. Here we used fMRI and multi-voxel pattern analysis to study the neural underpinnings of holistic object representation for faces and cars. We used a block design and extracted fMRI response pattern from predefined regions of interest (ROI) in lateral and ventral visual cortex for object parts either presented alone, together in the correct configuration or in a scrambled configuration. We first trained our classifier to distinguish between the patterns evoked by the intact and the scrambled object images using support vector machine. We then averaged the patterns evoked by the individual parts presented alone to create a synthesized pattern and asked the trained classifier to classify this synthesized pattern. If holistic object representation is not coded in an ROI, because the synthesized image looks as dissimilar to the intact as it does to the scrambled object, the synthesized pattern should be classified at chance as either an intact or a scrambled object. However, if holistic object representation is coded in an ROI, because only the intact object pattern contains such information, the synthesized pattern would be more likely to be classified as a scrambled than as an intact object. For faces, only the right fusiform face area (FFA) exhibited such response bias; and for cars, only the right lateral occipital (LO) area did so. All other object areas examined showed no classification bias. These results indicate holistic face processing in the right FFA and holistic car processing in the right LO. Together they suggest that right visual object areas play important roles in representing holistic object information, with different right visual object areas representing such information for different categories of objects.

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24.24, *3:15 pm*

The evolving representation of objects in the human brain.

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Early functional magnetic resonance imaging (fMRI) studies revealed a constellation of areas in ventral occipital and temporal cortices (VOT) that respond selectively to objects, and areas that respond selectively to specific categories of objects (e.g. faces). Using pattern analysis and a large number of object exemplars, fMRI studies later observed object-category information to be distributed across VOT. More recently, studies have found that the brain maintains a representational space of objects, in which conventional categories form clusters and individual exemplars can be differentiated. In the present study, we used magnetoencephalography (MEG) and pattern analysis to examine how this representational space emerges over time. Participants viewed exemplars of six categories of objects (human faces, animal faces, human bodies, animal bodies, natural objects, and man-made objects) while brain activity was recorded using MEG. Using a temporal sliding window, we studied the pattern similarity of the stimuli in the evoked response. The analysis revealed a dynamic representation that evolves over time. Shortly after stimulus onset, the evoked patterns for exemplars became distinct for individual exemplars with no apparent coherence among categories. Human faces then emerged as a distinct category. The geometry of the space then evolved to a state that exhibited a predominant structure distinguishing between animate and inanimate objects. Shortly thereafter, substructure emerged within this structure that distinguished animate object categories (human faces, animal faces, human bodies, animal bodies). The outcome of the study shows that the brain's representation of objects dynamically changes over time, presumably reflecting distinct stages in the visual processing of objects.

24.25, *3:30 pm*

Task-dependent representations of visual objects

Assaf Harel[1](assaf.harel@nih.gov), Dwight Kravitz[1], Chris Baker[1]; [1]National Institute of Mental Health, National Institutes of Health

One of the longest-standing questions in object recognition is how malleable object representations are to top-down cognitive factors. While behavioral studies suggest that knowledge, experience and expectations modulate the representation of objects, less is known about how the neural object responses are modulated by such top-down factors. Here, we studied how the observer's current goals modulate cortical object representations by examining neural responses elicited by the same visual image under multiple types of tasks. Specifically, we examined whether the current task could be decoded from the multivoxel response patterns in object-selective cortex. In a fully-interleaved event-related fMRI design, participants categorized objects from eight categories (e.g. cows, flowers, motorbikes) under six different tasks. Half the tasks required stimulus-based perceptual judgments (e.g. stimulus orientation) and half required more conceptually-based judgments (e.g. animacy). Critically, all images were presented in all tasks, circumventing any associations between task and visual information. We found that both the response magnitude and response patterns in object-selective cortex differed between tasks, particularly between the semantic and perceptual tasks. In particular, response magnitude was higher in the perceptual relative to the semantic tasks (both types of task equated for difficulty) and the two types of tasks could be decoded based on their response patterns. Further, while individual perceptual tasks were highly discriminable, the semantic tasks all elicited similar patterns of response. Looking at the whole brain activity, different tasks had distinct signatures, with activity spanning frontal and parietal as well as occipito-temporal regions. While the semantic tasks elicited strong activation in lateral frontal cortex, the perceptual tasks predominantly engaged more posterior regions. These findings provide initial evidence that object representations in object selective cortex are flexible and depend on task. However, the type of task matters: whereas stimulus-based tasks were clearly distinguished, the conceptually-based tasks did not elicit differential representations.

Acknowledgement: NIMH Intramural Research Program

Saturday PM

Saturday PM

24.26, *3:45 pm*

The reference frame of object files: robust coupling of object information to the reference frame

Zhicheng Lin[1](zhichenglin@gmail.com), Sheng He[1]; [1]Department of Psychology, University of Minnesota, Twin Cities

As objects in the environment move, a major challenge for the visual system is to keep track of each individual object. One suggested solution is to tag each object in an object file that could continually update information about its current characteristics. In a series of experiments, we show that the construction of object files is robustly coupled to their reference frames. Based on apparent motion, we developed a psychophysical method where two frames were shown in sequence, with the first frame centered on the fixation and the second frame on the upper left, upper right, lower left, or lower right corner. Two preview letters were presented on the first frame (one on the left and one on the right of the fixation), followed by a target letter on the second frame (target letter right above or below the fixation). Subjects were asked to indicate whether the target letter was one of the two preview letters. Critically, when the target letter was one of the preview letters, it shared the same relative location either as the same preview letter (e.g. both on the left side of each frame) or as the different preview letter. Despite that the target letter was equidistant from the two preview letters, we found that sharing the same frame-location as the same preview letter improved performance. This demonstrates that the construction of object files of the two preview letters was reference frame specific. We further found that this effect 1) was preserved when no competition was involved (e.g. when only one preview letter was presented), 2) occurred in a perceptual discrimination task with no memory demand (e.g. when the preview letters were task irrelevant and uninformative), and 3) held even when the preview letters were visually equally similar to the target letter (e.g. b-B, p-B).

Acknowledgement: NSF BCS-0818588 and NIH T32EB008389

24.27, *4:00 pm*

The cortical demands of two kinds of perceptual task

Denis G. Pelli[1,4](denis.pelli@nyu.edu), Martin T. Barlow[2,4], Horace B. Barlow[3,4]; [1]Psychology and Neural Science, New York University, [2]Dept. Mathematics, University of British Columbia, [3]Dept. of Physiology, Development and Neuroscience, University of Cambridge, [4]Trinity College, University of Cambridge

Many authors distinguish “first-order” object recognition from “second-order” tasks that are poorly suited to template matching and seem to demand other kinds of perceptual computation. “Second-order” tasks include detecting symmetry, Glass patterns, modulations of white noise, and coarse patterns composed of small balanced elements. Past treatments have suggested various special computations, particular to each task, that observers might make. We take a more general approach. We suppose a complete set of receptive fields (like those of V1 cells) and ask how many receptive fields are required to perform as well as human observers. This is like defining efficiency as the fraction of available information (e.g. dots or area) that would be required by an ideal observer, but applied to receptive fields rather than to components (e.g. dots) of the stimulus. With mild assumptions about the receptive fields, this reveals a dichotomy between “first-order” ordinary identification tasks that require on the order of ten receptive fields and “second-order” tasks that require thousands or millions. The necessary cortical wiring is greatly affected by the hundred-or-more-fold increase in the number of receptive fields used.

Acknowledgement: NIH R01-EY04432 to DGP

3D perception

Saturday, May 12, 5:15 - 6:45 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Lawrence Cormack

25.11, *5:15 pm*

A unified approach to estimating shape from images

Phillip Isola[1](phillipi@mit.edu), Forrester Cole[1], Bill Freeman[1], Fredo Durand[1], Edward Adelson[1]; [1]MIT

Humans are able to interpret an object’s 3D shape from a single image. If the lighting is changed, or the object’s BRDF is changed, there may be large changes in the image, yet the perceived shape tends to remain the same. Humans can also perceive 3D shape from line drawings, although the image corresponds to no realistic physical process. There have been many attempts to give similar capabilities to computer vision systems, and this has led to multiple specialized systems such as “shape from shading” (assuming Lambertian surfaces), “shape from texture” (assuming a stationary texture process), and “shape from line drawings,” (assuming lines are drawn at specific places). However, a unified solution has been lacking. Here, we take a step toward unification. We have built a computer vision system that can be trained to estimate 3D shape from multiple types of image data. The system operates by matching localized image patches with shape candidates from a training database of exemplars. We construct a graph of compatibility relationships between nearby patches and infer a globally consistent interpretation using loopy belief propagation. A major difficulty in applying an example-based approach to shape interpretation is the combinatorial explosion of shape possibilities that occurs at occluding contours. We introduce a new shape patch representation that allows for flexible matching of overlapping patches, avoiding the combinatorial explosion by letting patches explain only the parts of the image they best fit. Our method can thus interpret objects with multiple layers of depth and self-occlusion, and, because it is data-driven, it can interpret these objects whether they are rendered with matte surfaces, glossy surfaces, textured surfaces, or line drawings. In tests, our system proposes shape interpretations that are almost always qualitatively correct.

Acknowledgement: P.I. is funded by an NSF Graduate Research fellowship.

25.12, *5:30 pm*

Perceived depth in photographs: humans perform close to veridical on a relative size task.

Maarten Wijntjes[1](M.W.A.Wijntjes@tudelft.nl), Sylvia Pont[1]; [1]Perceptual Intelligence Lab, Industrial Design Engineering, Delft University of Technology

We address the issue of measuring the perceived spatial layout of pictorial space. We focus on a modified version of a recently developed relative size task in which observers had to equalize the relative sizes of an object pair in pictorial space. In our version of the task, one object was used as a fixed size standard probe throughout each experimental session. Two photographs were used, both of the interior of a campus building entrance hall. 53 and 61 pictorial sample points were selected, respectively. We collected ground truth data of the actual scene by measuring for each point the distance to the camera with a laser distance meter, ranging from 9 to 46 meter. Five observers each completed 12 experimental sessions: two photographs, two standard probe positions and three repetitions. The repeated trials consistency, quantified by the coefficient of determination, was generally high: on average 0.86 (lowest 0.72 and highest 0.94). The mean results of the three repetitions were used for further analysis. For pictorial relief (3D shape) it has been previously found that observers use different mental viewpoints, as quantified by an affine transformation resolving differences between observers. In our spatial layout experiment, we found very few of these cases. This could indicate a categorical difference in perceiving surface relief and spatial layout. Furthermore, we compared the observer settings with the ground truth data. Perhaps surprisingly, we found that observers were generally very close to the ground truth. Coefficients of determination between observers’ settings (averaged over three repetitions) and ground truth data were on average 0.93 (lowest 0.88 and highest 0.97). Overall perceived depth was not consistently more compressed or stretched than the actual depth. Also, no significant affine correlations were found. The results seem to suggest that humans perceive pictorial spatial layout differently from pictorial relief.

Acknowledgement: This work was supported by a grant from the Netherlands Organization of Scientific Research (NWO).

25.13, *5:45 pm*

Estimating Range From Luminance

Che-Chun Su[1,3](chechunsu@mail.utexas.edu), Alan Bovik[1,3], Lawrence Cormack[2,3]; [1]Department of Electrical and Computer Engineering, The University of Texas at Austin, [2]Department of Psychology, The University of Texas at Austin, [3]Center for Perceptual Systems, The University of Texas at Austin

Estimating range (egocentric distance) is a difficult problem generally approached by using a combination of well-known depth cues. Here, we take a different approach that exploits statistical relationships between local image structure and depth structure. First, we collected 12 high-resolution RGB images co-registered with precise range data using a combination RIEGL VZ-400 range scanner and a Nikon D700 camera. We subdivided these images and the corresponding range maps into 16 x 16 patches. The range patches were pre-processed (normalization, gradient extraction) and then clustered (k-means) to form a "dictionary" of canonical range structures. Then, 11 of the images were used to train an optimal classifier to associate image patches (or, more precisely, the corresponding outputs of a V1-like wavelet filter bank) to these canonical range structures. The 12th range map was then reconstructed by, first, having the Bayesian classifier select the most likely range patch for each image patch and, second, stitching the range patches together via simple averaging. The reconstructed range maps look remarkably like the actual range maps given that no conventional depth cues (including binocular disparity) were used. Quantitative comparison shows that the estimated range values correlate to the ground-truth range values fairly well. This implies that a biological visual system might be able to make a coarse estimate of range structure in the environment using the retinal image at hand and associations between image structure and true range structure, associations that could be learned via interaction with the environment over either developmental or evolutionary timescales.

Acknowledgement: National Science Foundation (NSF) grant #IIS-0917175

25.14, *6:00 pm*

Human defocus blur discrimination in natural images

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Defocus blur is a useful cue in many natural tasks. Although blur discrimination has been studied extensively, defocus sensitivity in natural scenes has not been systematically investigated. Here, we use a collection of natural image patches, sampled from well-focused photographs, to measure discrimination of blur created by the eye's optics. We constructed a psychophysical rig capable of presenting stimuli at three physical distances simultaneously along the line of sight. Half-silvered mirrors combined the light from three monitors positioned at variable distances from the subject. The stimuli were rendered sharply on each monitor so that defocus blur was created by the optics of the subject's eye, as in natural viewing. A calibration procedure eliminated spurious geometrical, color, and luminance cues. Subjects viewed stimuli monocularly through a 4 mm artificial pupil. Accommodation was not paralyzed. At the beginning of each trial, subjects judged the orientation of a low-contrast, high-frequency grating on the focus monitor. This ensured accurate accommodation at the focus distance of 80 cm. Next, two cosine-windowed natural patches were presented on the stimulus monitors for 150 ms. The task was to identify the sharper patch in a 2AFC paradigm according to method of constant stimuli (standard from 0.0 to 0.75 D). Discrimination thresholds varied substantially between stimuli but were correlated between subjects. Consistent with the literature, thresholds decreased with defocus pedestal. For comparison, the Maltese cross stimulus, the most widely used artificial stimulus in defocus research, yielded poorer performance than ~80% of natural stimuli, suggesting that the usefulness of defocus cues has been underappreciated. The lowest thresholds were at or below the lowest thresholds ever reported.

25.15, *6:15 pm*

What can observation variance tell us about the visual system's use of shape information?

Glen Harding[1](g.harding1@bradford.ac.uk), Julie Harris[2], Marina Bloj[1]; [1]University of Bradford, [2]University of St Andrews

Perception of three dimensional (3D) shape is typically biased. Bayesian models of perception attribute such biases to the influence of prior knowledge that acts to restrict perception to likely 3D shapes. However, an infinite set of Bayesian models can predict the same perceived shape, for even the simple situation of a single cue and associated prior. By further constraining a Bayesian model to predict observer variance for a task, one can understand more details of the cue and prior information (i.e. the shapes of the likelihood functions and prior distributions). We demonstrate a method of calculating the prior distributions and likelihood functions of a Bayesian model by considering settings made by observers in a 3D shape matching experiment. Stimuli contained an outline cue, a shading cue, or both. Observer estimates show a large bias towards frontoparallel surface orientation when using either cue, or a combination of both. A Bayesian cue combination model, constructed using Gaussian likelihood functions and prior distributions, can predict mean shape settings when observation variance is not considered. However, when the model is constrained to fit observation variance as well as mean shape settings, prior distributions that either depend on the stimulus or have heavy tails are needed. We conclude that strong priors affect observers' perception of shape in our stimuli, and that these priors must be represented by distributions that are heavier tailed than Gaussians, similar to priors that have been shown to explain biases in speed perception.

Acknowledgement: EPSRC grants EP/G038597/1 and EP/G038708/1

25.16, *6:30 pm* **The perception of shape from shading for Lambertian surfaces and range images**

James Todd[1](todd.44@osu.edu), Eric Egan[1]; [1]Department of Psychology, Ohio State University

In natural vision, the luminance in each local region of a matte surface is primarily determined by its local orientation relative to the direction of illumination. However, it is also possible to obtain compelling perceptions of shape from shading for range images, in which the intensity at each pixel location is determined by the relative depth of the closest surface region that projects to it. Although there are some situations such as spheres with point source illuminations where range images can be identical to a rendering based on Lambert's law, they are more commonly quite different from one another. Consider, for example, a valley that is bounded on both sides by ridges. In a cross-section through a Lambertian rendering there will be three intensity maxima – one for each ridge and one for the valley. For a range image, in contrast, there will only be intensity maxima on the ridges, and the valley will be marked by a local minimum of image intensity. The present research was designed to investigate observers' shape judgments for these two types of displays, and to model the expected pattern of performance using a shape from shading algorithm based on an assumed Lambertian reflectance function and a distant point source illumination. The stimuli included both Monge surfaces and deformed spheres, and we examined several different reflectance models and patterns of illumination. The results reveal some systematic differences among these conditions, but they are much smaller than what would be expected from classical shape from shading algorithms. These findings cast doubt on the common belief that the perceptual mechanisms for determining shape from shading are based on an implicit assumption that visible surfaces have Lambertian reflectance functions.

Acknowledgement: Supported by NSF grant BCS-0962119

Perceptual learning: Mechanisms

Saturday, May 12, 5:15 - 6:45 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Vikranth R. Bejjanki

25.21, *5:15 pm*

Perceptual learning incepted by decoded fMRI neurofeedback without stimulus presentation

Kazuhisa Shibata[1,2](kazuhisa@bu.edu), Yuka Sasaki[2,3,4], Mitsuo Kawato[2], Takeo Watanabe[1,2]; [1]Department of Psychology, Boston University, [2]ATR Computational Neuroscience Laboratories, [3]Athinoula A. Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, [4]Department of Radiology, Harvard Medical School

Whether adult early visual cortex has sufficient plasticity to allow for behavioral and/or sensitivity changes remains a point of great controversy. Many studies have examined how activity changes in the brain are correlated with visual performance improvements resulting from repetitive training, known as visual perceptual learning (VPL). However, such a correlational approach has not conclusively settled the adult plasticity debate, partially because most VPL studies have examined correlations between behavioral and neural activity changes rather than cause-and-effect relationships. To address the question of whether early visual areas are that plastic, we developed a new functional magnetic resonance imaging (fMRI) online-feedback method (Shibata, Watanabe, Sasaki & Kawato, 2011, Science), by which activation patterns only in early visual areas corresponding to the pattern evoked by the presentation of a real and specific target orientation stimulus were repeatedly induced without subjects' knowledge of what is being learned and without external stimulus presentation. Before and after fMRI online-feedback training for several days, subjects' performance on an orientation discrimination task was measured. We found that the mere induction of the activation patterns in early visual areas resulted in significant sensitivity improvement on the target orientation, but not on other orientations. Moreover, the induced activation patterns in early visual areas significantly correlated with sensitivity improvement on the

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target orientation. Activity patterns in other areas did not change in concert with the induced pattern in early visual areas, indicating no spillover of the patterns from the early areas. Our results indicate that the adult early visual cortex is so plastic that mere repetition of the activity pattern corresponding to a specific feature in the cortex is sufficient to cause VPL of the feature, even without stimulus presentation, conscious awareness of the meaning of the neural patterns that subjects induced, or knowledge of the intention of the experiment.

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25.22, *5:30 pm*

The differing effects of REM and non-REM sleep on performance in visual statistical learning

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Although visual statistical learning (VSL) has been established as a method for testing implicit knowledge gained through observation, little is known about the mechanisms underlying this type of learning. We examined the role of sleep in stabilization and consolidation of learning in a typical VSL task, where subjects observed scenes composed of simple shape combinations according to specific rules, and then demonstrated their gained familiarity of the underlying statistical regularities. We asked 1) whether there would be interference between learning regularities in multiple VSL tasks within close spatial and temporal proximity even if the shapes used in the tasks were different, and 2) whether sleep between interfering conditions could stabilize and consolidate the learning rules, improving performance. Subjects completed four separate VSL learning blocks, each containing scenes composed of different shapes: Learning A and B were presented sequentially, Learning B and C were separated temporally by two hours, and Learning C and D were separated by a period of similar length in which subjects either took a nap which included or excluded REM sleep, or remained awake, either quietly or actively. Familiarity tests with the four structures were conducted following Learning D. If sleep blocks interference, we would expect to see interference between Learning A and B, and not between Learning C and D. If sleep increases learning, performance would be best on the test of Learning D. We found indications of interference between Learning A and B, but only in the non-REM nap group. Also, a significantly improved performance on the Learning D familiarity test was found, but only in the REM nap group. Thus, knowledge gained by VSL does interfere despite segregation in shape identity across tasks, a period of stabilization can eliminate this effect, and REM sleep enhances acquisition of new learning.

25.23, *5:45 pm*

Spontaneous Recovery of the Motion Aftereffect

Juraj Mesik[1](thewunneh@gmail.com), Stephen Engel[1]; [1]Department of Psychology, University of Minnesota

Prolonged viewing of motion produces illusory movement in stationary displays, called the motion aftereffect (MAE). During motion processing, outputs of direction-selective mechanisms are combined to produce a global percept. Where in this hierarchy are MAEs produced? If MAEs arise early, then adaptation to different directions may be controlled by distinct direction-selective mechanisms. We tested this by examining whether MAEs in one direction eliminate MAEs in another direction or simply temporarily mask them. Subjects fixated while attending a sine-wave grating moving either leftward or rightward (direction “AB”). Following 10-minutes of viewing, the motion reversed (to direction “BA”), and every 4 seconds a static pattern appeared and subjects indicated their perceived direction of illusory motion. The BA motion continued until subjects perceived MAEs in the AB direction (on average 24 sec). Then, in a final test phase, the static stimulus was presented for 90 seconds, while subjects continued to report their MAE every 4 seconds. Subjects’ final test phase MAE initially reflected the recent BA adaptation (i.e MAE in AB direction). Within 10 seconds, however, the MAE of all subjects (n=7) reversed direction to reflect the original, longer-term AB adaptation (i.e. in BA direction), which then persisted until the end of testing. The simplest account of our data is that adaptation in the two directions is controlled by distinct mechanisms. Following the long AB and shorter BA adaptations, both mechanisms were active, but BA adaptation was momentarily stronger. Because the BA adaptation was shorter, however, it decayed more quickly than the AB adaptation during the final test phase, unmasking the remaining AB adaptation and allowing its MAE to spontaneously recover. These findings suggest that adaptation occurs in early direction-selective stages of motion processing, and illustrate the visual system’s ability to adapt to short-term changes while retaining information about longer-lasting visual conditions.

Acknowledgement: Supported by NSF BCS-1028584

25.24, *6:00 pm*

Perceptual learning in amblyopes: A cautionary tale

Lynne Kiorpes[1](lynne@cns.nyu.edu), Paul Mangal[1]; [1]Center for Neural Science, New York University

Perceptual learning is gaining recognition as a potentially beneficial treatment for adults with amblyopia. However, it is unclear how consistent the training benefit is across subjects and tasks. We investigated this question in amblyopic non-human primates (Macaca nemestrina). We used an integrative training stimulus: random dot motion direction discrimination over a range of directions and dot speeds. We then tested for improvement in performance on various motion and form tasks post-training: coherent motion detection, Glass pattern form discrimination, contrast sensitivity, and Vernier acuity. As a control, we assessed the untrained fellow eye for any changes in performance. All data were collected using two-alternative forced-choice psychophysical methods. Four amblyopic monkeys, two strabismic and two anisometropic, and one visually-normal control were tested. The number of training trials for perceptual learning ranged from 15,000 – 30,000. Our results showed that 1) at least 20,000 training trials were needed for substantive perceptual learning to occur; 2) in most cases, learning transferred within the training domain to a non-practiced motion task, but there was less transfer across domains, to the spatial tasks; 3) contrast sensitivity improved in one-half of the cases but was poorer after training in the other cases; 4) form discrimination performance was typically poorer after training, with only 1 of the 4 amblyopes showing a clear training benefit; 5) Vernier acuity was mostly unaffected by the training; 6) in several cases, serendipitous improvement in the untrained fellow eye negated any benefit to the amblyopic eye. These results suggest that further evaluation is needed before perceptual learning can be considered a consistent, broadly effective and beneficial treatment for amblyopia.

Acknowledgement: NIH EY05864

25.25, *6:15 pm*

Decoupling orientation specificity from perceptual learning in amblyopic vision

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Perceptual learning (PL) has been shown to improve many visual functions in amblyopes, but this learning is often specific to the trained orientation, possibly implying neural plasticity in the amblyopic early visual cortex. However, orientation specificity in normal vision can be decoupled from PL with a training-plus-exposure (TPE) technique (Zhang et al., JNS2010). Specifically, PL transfers to an untrained orthogonal orientation when training is accompanied by additional exposure of the transfer orientation when an irrelevant task is performed. The transfer suggests PL occurs in higher brain areas. Here we used the TPE technique in adults with amblyopia to investigate whether PL reflects V1 plasticity or improved high-level decision making in the amblyopic brain. Eighteen adult amblyopes participated. Similar to normal vision we found: (1) PL of contrast discrimination in the fovea of amblyopic eyes (AEs) did not transfer to an orthogonal orientation. However, AEs were then exposed to the orthogonal transfer orientation through irrelevant orientation discrimination training at the transfer orientation, which enabled contrast learning to transfer to the orthogonal orientation. (2) We found similar transfer in the AEs after the non-amblyopic eyes (NAEs) were exposed. (3) Orientation specificity in Vernier and orientation learning was also eliminated by exposure of the transfer orientation in AEs or NAEs through irrelevant orientation or contrast training. (4) Surprisingly, orientation specificity in NAE Vernier learning was eliminated after AEs were exposed to the orthogonal transfer orientation, indicating that the AE can teach the NAE. TPE enabled learning transfer across orientations suggests that perceptual learning in amblyopic vision may not reflect plasticity in local circuits in the amblyopic early visual cortex. Rather

it may result from improved readout of noisy stimulus inputs at the decision stage that, at least in part, compensates for the functional deficits in the amblyopic visual system.

25.26, *6:30 pm*

Evidence for action video game induced 'learning to learn' in a perceptual decision-making task

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Action video game play benefits performance in an array of sensory, perceptual, and attentional tasks that go beyond the specifics of game play. Rather than reflecting an enhancement in myriad independent cognitive abilities, we have recently suggested that this may reflect a singular improvement in the ability to perform statistical inference on sensory data (Green, Pouget, Bavelier, 2010). Using a perceptual decision-making task and a classical diffusion-to-bound model, action video game play was found to result in an increased rate of information accumulation and a decrease in decision bound, resulting in more correct decisions per unit of time and reflecting better statistical inference. Here, we ask how performance differences may emerge between action gamers and non-action gamers. A general change in sensitivity could be at play, predicting performance differences on the very first trial. Alternatively, an improved ability to learn task-relevant statistics may also account for the data. This latter view predicts comparable performance between groups initially, with group differences only emerging as participants gain experience with the task. To test these hypotheses, participants underwent four days of a dot-motion perceptual decision-making task. Consistent with the learning to learn hypothesis, a hierarchical Bayesian analysis of the behavioral data using an extended diffusion-to-bound model demonstrated that while parameter values were indistinguishable early in the experiment, differences in learning rate emerged quickly, with gamers clearly outpacing non-gamers. Combined with the fact that gamers also continued to show significant learning for a greater proportion of the total experiment (i.e. their performance plateaued later), this resulted in significantly more total learning in gamers. In sum, the true advantage conferred by action video game experience may be the ability to efficiently learn the statistics of novel task environments, an account that would naturally explain the breadth of tasks shown to benefit from such training.

Acknowledgement: This work was supported in part by EY016880, and by the Office of Naval Research (MURI Program) to D. B.

Saturday Afternoon Posters

Visual memory: Load, grouping, familiarity

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

26.301 Rapid forgetting due to binding failures in working memory

Yoni Pertzov[1](pertzov@gmail.com), Sabine Joseph[1], Mia Dong[1], Elke Reunis[1], M Paul Bays[1], Masud Husain[1]; [1]UCL Institute of Neurology, Queen Square, London, UK

Forgetting impacts on almost all aspects of cognitive function in everyday life. But in spite of its significance, the underlying mechanisms remain unclear. It has been suggested that a rapid decrease in memory performance is a result of gradual fading or sudden termination of memory representations as time passes. But others contend that interference from newly encoded items, rather than the passage of time, is the key mechanism underlying forgetting. We studied the precision of memory recall, varying the number of items and duration of delay. Critically, in addition to analysing subjects' reports with respect to the true values of the probed object, we also studied whether their recall might be biased by other items in the memory array that were not probed. Our results support a novel perspective about the factors responsible for short term forgetting. Both time and interference are essential for forgetting and interact in a highly specific manner. While single items can be maintained in memory with high fidelity, additional items degrade each other's representation as time passes by competing in working memory. Specifically, interference between items is associated with decreasing precision caused by increased probability of binding failures - as evidenced by increasing report of features of non-probed items. Thus, while memory of single features is fairly robust across time, the links connecting different features belonging to an object are the ones most vulnerable to degradation and forgetting.

26.302 Distractor processing in low perceptual load is determined by the availability of visual short-term memory resources

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Recent additions to the early versus late attentional selection debate have led to the conceptualization of perceptual load theory which states that task-irrelevant stimuli can only be ignored when resources are sufficiently taxed to engage selective attention. However, the nature of the resources that are putatively depleted under high perceptual load is ill-defined. Because many experiments designed to examine perceptual load have employed brief exposure durations, it is tenable that visual short-term memory (VSTM) may play a role in visual selection under high perceptual load conditions. Overly-limited exposure durations would force observers to perform the task on an internal representation of the stimuli due to fleeting bottom-up support from the display. A consequence of the demand placed upon internal maintenance of task-relevant information coupled with greater entropy in high perceptual load displays may manifest itself as elevated demands on VSTM consolidation compared to the demands engendered by relatively austere low perceptual load displays. With that, we predicted that a concurrent VSTM load would reduce observers' capacity to internally represent task-relevant stimuli thereby allowing low perceptual load displays to reveal the resource limitations of high load displays. However, if VSTM taxes cognitive processes involved in distractor suppression (Lavie et al., 2004, JEP:General), then a VSTM load would increase distractor interference in low load displays. We found a significant flanker effect when subjects had to store one item in VSTM. The effect dissipated as VSTM load grew to two, three, and four items. A second experiment ruled out low-level perceptual influences of the VSTM displays. These results reveal that a concurrent VSTM load acts to reduce available resources which would otherwise be free to process task-irrelevant stimuli in low perceptual load. We propose that the resources taxed by high 'perceptual' load are in fact mnemonic rather than perceptual in nature.

26.303 Task-dependent representations in Visual and Frontal Cortex during Working Memory

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Working memory is the process by which absent items are actively processed and maintained in memory in order to guide future action. This function has been associated with activation of prefrontal cortex, but it remains unclear whether the information of working memory is always stored in the prefrontal cortex independent of behavioral goals. Here, we used functional magnetic resonance imaging (fMRI) at 7 Tesla to investigate the representation of information about visual objects (watches, clocks, teapots, kettles, scooters and motorbikes) in occipitotemporal visual areas and frontal cortex during two delayed-match-to-sample tasks emphasizing different aspects of the objects. In both tasks, two sample object images were presented sequentially followed by a cue, indicating the particular sample object to be remembered, a delay and then a test image. In the "Part" task, participants were asked to decide whether an object part presented after delay period belonged to the remembered object. In the "Category" task, participants were asked to determine whether the test image was in the same category as the sample object. We used a searchlight procedure to identify cortical regions allowing decoding of remembered objects based on the multi-voxel response pattern during the delay period. In the Part task, the response of occipitotemporal but not prefrontal regions could be used to decode the identity of individual remembered objects. In contrast, during the Category task, prefrontal, but not occipitotemporal regions, showed significantly distinct representations for each remembered object. Neither visual nor frontal areas showed any significant decoding for the unremembered object. These results show that the distribution of object information held in working memory is dependent on the nature of the task - object-selective areas are primarily involved in maintaining visual, but not semantic information whereas prefrontal areas are primarily involved in maintaining category information.

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26.304 Working Memory Load Increase Predicts Visual Search Efficiency

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The size of an observer's pupil varies with factors such as ambient luminance, arousal, cognitive effort, and working memory load. Since it is difficult to measure working memory load during an ongoing task, the ability to estimate it via pupil size recording could benefit many fields of research. One important paradigm for such application is visual search, whose utilization of working memory has been the subject of long-standing debates. Porter, Troscianko, and Gilchrist (QJEP 2007) found that pupil size statistically increased over the course of the search, and they attributed this finding to accumulating working memory load. However, other factors, e.g., arousal and effort, likely affected pupil size as well and added noise to the data and some uncertainty to the conclusions. In the present study, we interspersed a simple search task (find the "T" among "L"s) with intermittent blank screens showing only a central fixation marker, thought to induce a low, stable level of arousal and cognitive effort. Consequently, differences in minimum pupil size between successive fixation screens should mainly reflect changes in working memory load that occurred during the search interval between the screens. A within-subject analysis showed that this pupil size difference between the first two fixation screens was a significant predictor of RT in the same trial, with an inverse correlation of approximately $r = -0.4$, indicating that greater pupil size increase tended to be followed by shorter search time. Furthermore, the difference in average, minimum, or maximum pupil size between the first two search display presentations did not predict RT, $|r| < 0.07$. These results show that (1) working memory load increases during search, (2) this load increase is a major

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factor determining search efficiency, and (3) intermittent fixation screens greatly enhance pupil-based memory load estimation, even providing trial-by-trial insight into the utilization of working memory.

26.305 **A load-specific influence of stimulus category on short-term memory for object and position**

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Categorical information is known to benefit visual short-term memory (VSTM); however, the degree to which memory load influences the exploitation of categorical information is unclear. In this study, 20 human adults completed an object/position recall experiment with two conditions, in which the memory display comprised a sequence of two (low memory load) or four (high memory load) Snodgrass stimuli presented sequentially, each for 400 ms, at one of 64 random locations. Stimuli belonged to one of 14 semantic categories (four-footed animals, insects, fruits, etc) tested equally often. A concurrent verbal loading task was performed. At test, in the object memory condition, a spatial marker appeared at the location of one of the memory stimuli, selected at random. Observers reported (verbally) the name of the stimulus shown at this location. In the position memory condition, a test stimulus was shown above the memory display area, together with numbered markers at each memory stimulus location used. Observers reported the number corresponding to the location of the test stimulus in the preceding memory display. Recall rates were analyzed using one-way repeated measures ANOVA (with stimulus category as a within-subjects factor) for each memory load. At high memory load, a significant effect of stimulus category was observed in both experimental conditions [object memory, $F(13, 247) = 4.87$, $p < 0.01$; position memory, $F(13, 247) = 2.67$, $p < 0.01$]; at low memory load, a significant effect of stimulus category was observed only in the object memory condition, $F(5.18, 97.23) = 4.87$, $p = 0.02$. These findings suggest that categorical information is exploited for both object and position memory tasks at high memory loads, but, at low memory loads it is exploited only for object memory. This may reflect the propensity to recruit additional (non-visual) stimulus information only where VSTM is stretched by task demands.

26.306 **Selective Impact of Mental Abstract Tasks on Visuospatial Short-Term Memory**

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Recent findings of neuroimaging and neuropsychological studies suggest that brain regions with visual-spatial characteristics are involved in a wide range of working memory tasks that require memory manipulation (Olson and Berryhill 2009). The spatial registry hypothesis (Noori and Itti 2011) provides an account for these findings by assuming a functional role for brain regions with visual-spatial encoding features in registering task-relevant working memory items in a spatially-organized short-term memory. These spatial registries may then be used as a reference to the items of the working memory for selective processing through shifting the spatial attention towards the registry locations. This hypothesis predicts that the impact of a secondary executive working memory task on the visuospatial short-term memory is selective to regions of the space that are being used for the corresponding registry process. We test this prediction by investigating the impact of the mental sorting of four characters on the visuospatial short-term memory of visual targets along horizontal and vertical directions. Our results show that when the working memory is engaged in the maintaining of four characters, the error rate in recalling horizontally spanned targets is significantly lower than vertically spanned targets (respectively 20.7%(M) +/- 2.4%(SEM) and 30.7%(M) +/- 3.7%(SEM) (ttest;n=15,p<0.0202)). However when subjects rearrange those characters in an ascending order, the error rate for horizontal targets significantly increases to 33.2%(M) +/- 2.8%(SEM) (ttest;n=15,p<0.00097) while the error rate for vertically spanned targets does not show a significant change (ttest;n=15,p>0.53). In a control experiment subjects are assigned a double counting task concurrent with retaining locations of two targets located on a circle. Doubling the signal rate for the mental task did not affect the error rates in recalling the location of the visual targets. This finding suggests that the observed impact might not be associate to deferring potential rehearsing process in the visuospatial short-term memory.

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26.307 **Grouping Principles in Visual Working Memory**

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It is well known that Gestalt grouping principles facilitate visual perception. However, it is unclear how or to what extent these grouping principles benefit visual working memory (VWM). Because VWM is subject to strict capacity limitations, anything that facilitates VWM could serve to significantly expand VWM capacity. Previous findings show that at least two grouping mechanisms, proximity and physical connectedness, can improve VWM accuracy (e.g. Woodman, Vecera, & Luck, 2003). Here, we tested VWM performance when visual stimuli could be grouped by proximity and/or similarity of color. In Experiment 1, we briefly presented supercapacity arrays (16 items: 4 items of 4 colors) to undergraduate participants. Stimuli were either grouped according to color or the colors were intermingled. After a brief delay (1000 ms) a single probe item appeared. Participants judged whether the color of the probe item was the same or different. When the stimuli were grouped according to color VWM accuracy was significantly higher than when items were not grouped. These data replicated previous findings showing VWM can also benefit from Gestalt grouping. Yet, other grouping manipulations were not so robust. In Experiment 2, we investigated whether the presence of multiple grouping principles in the same visual array could result in additive benefits for VWM performance. Using 6 horizontally arrayed color patches we tested grouping by similarity and proximity using four conditions: no grouping, color grouping, proximity, and color + proximity. VWM accuracy was significantly modulated by grouping, but in an unexpected direction. VWM accuracy in the color + proximity condition was significantly lower than either of the other two grouping conditions. These results indicate that Gestalt principles of perceptual grouping are not automatically instantiated in VWM and consequently, do not always enhance VWM capacity.

26.308 **Impact of Gestalt Grouping on Objects in Spatial Working Memory**

Melissa A.B. Smith[1](mabsmith@gmail.com), Eric Blumberg[1], Matthew S. Peterson[1]; [1]Psychology Department, George Mason University

Previous research has found that Gestalt principles of organization can affect how objects are stored in working memory (Woodman, et al, 2003). However, it is not clear whether this effect is due to how stimuli are encoded or how they are organized in storage. The studies presented here examine how Gestalt grouping, in the form of an enclosing figure, affects the spatial locations of objects already stored in memory. It was hypothesized that Gestalt grouping would impact the accuracy of recall of the memorized elements. Four dots were displayed briefly on a computer monitor, followed by a dot masking screen, and another presentation of four dots either in the same arrangement or with one dot in a different spatial location. During the retention interval, between the dot mask and the second presentation of the dots, either two Gestalt-grouping figures (experimental condition) or two groups of random lines (control) that coincided with locations of the Gestalt figures were presented for 2000 ms. Results demonstrated that the Gestalt grouping had a negative impact on the accuracy of spatial recall only when the dots moved from a location that corresponded to the interior of a figure to another interior location. The presence of the Gestalt figures during the retention interval had no effect for detecting dots that moved outside the figures or between the interior of the figure and the background. These findings suggest that object grouping does play a role in how items are stored in working memory, and grouping can have its effects after items have already been encoded.

26.309 **Influence of category knowledge on change detection performance**

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Although people can fail to detect surprisingly large visual changes (i.e. change blindness), we are somewhat more likely to notice changes relevant to our interests or expertise (e.g., Werner & Thies, 2000; Rensink, O'Regan & Clark, 1997). Pre-existing knowledge and interest may guide attention toward self-relevant information, making it more likely that details necessary for detecting changes to that information will be encoded. Experience might also alter how well and what kind of information is mentally represented, making changes that conflict with those representations more

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noticeable. For example, changes that cross known category boundaries are more likely to be detected (e.g. Hollingworth & Henderson, 2002; Simons & Levin, 1998). In this study, we trained subjects to classify 12 novel line-drawn aliens into two categories during 84 training trials. The aliens varied along six feature dimensions and four of those features were randomly selected to be diagnostic of alien category for each subject. Subjects then completed 320 trials of a one-shot change detection task where they saw a single novel alien appear in a jittered central location on the screen, disappear, and then reappear. On 66% of trials, the alien changed on two feature dimensions, each of which was previously either diagnostic of category or not. Replicating previous work (Williams & Simons, 2000), subjects were biased to report seeing the same alien after category training. Moreover, as predicted by change detection studies involving natural categories, subjects were better at detecting changes that altered the alien's category than changes that did not. Subjects were also more likely to detect a change that involved more diagnostic features, even though category information was not predictive of the changes. This finding suggests that even limited experience with category information can influence the perceptual routines and judgments involved in detecting visual change.

26.310 Object identities facilitate response to a target in spatio-temporal contextual cuing

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Previous studies demonstrated that attention could be guided to a target object when the spatial configuration of the objects in a search display was repeated (contextual cuing; Chun & Jiang, 1998). Recent studies further demonstrated that the sequence could be implicitly learned and enhance attentional processes (Olson & Chun, 2001; Mayberry et al., 2010). It is not clear, however, whether the spatial and temporal contexts are learned at the same time, or one is selectively learned when two redundant contextual cues are presented. In the present study, we developed a spatio-temporal contextual cuing paradigm to address this issue. Participants were asked to respond to a target object among the stream of distractors that were presented sequentially at different locations. In the learning phase, invariant sequences associated with a particular target were presented repeatedly. The invariant sequences consisted of six objects which were presented fixed locations in the same order. In the following test phase, both the locations and identities of the distractors (Experiment 1), those locations (Experiment 2), or those identities (Experiment 3) were randomized in the learned sequences. The results showed that reaction time became longer in the test phase than in the last block of the learning phase when the object identities of the invariant sequences were randomized (Experiments 1 and 3). In contrast, reaction time was unaffected when the object locations in the invariant sequences were randomized (Experiment 2). The participants could not recognize the invariant sequences in all experiments. Furthermore, eye movements during the learning phase showed that processing for target identities was facilitated whereas prediction of target location was not facilitated (Experiment 4). These results suggest that the participants selectively learned object identities even though both spatial and temporal information in the invariant sequence is available for a target prediction.

26.311 Recollection and familiarity for rotated objects

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One challenge in recognizing 3D objects is the variability in visual information that they present to our visual system. In order to identify objects in the future, do we store information that generalizes over changes in viewing perspective (view-invariant), or do we instead encode visual information that is specific to a particular viewing experience (view-specific)? When experimenters test this question they normally use a single memory task (e.g., old-new identification), but different memory tasks have been shown to produce distinct patterns of performance with the same perceptual input. Therefore, the process-dissociation procedure was used to get separate estimates of recollection (specific memory for an event) and familiarity (heightened activation of an encountered item in the absence of recollection) for rotated objects in a recognition task. Participants studied sets of familiar objects, with each object in each set presented individually. In a later test, participants were shown old and new objects; for old objects, they also had to try to remember which set the object had been presented in. This method enables independent estimates to be gained for recollection (remembering the set in which the object was presented) and familiarity (knowing the object was presented but lacking knowledge of the set it was presented in). These measures showed that recollection was better when the test view matched the studied view (or showed a very similar visual appearance), but that familiarity was viewpoint invariant. As such, these results suggest that the visual system encodes information about objects that can be utilized in different ways by different memory systems, depending upon the specific requirements of a given task. Further, they suggest that the "viewpoint debate" between view-specific and view-invariant models is intractable, because both patterns of data are found with the same set of objects across different memory measures.

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26.312 Pre-experimental familiarity modulates the effects of item repetition on source memory

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Recent studies have reported conflicting findings on the effects of item repetition on item-source binding: Some demonstrated better source memory for repeated items than unrepeated ones, while others found negative relationship between the frequency of repetition and source memory accuracy. In order to reconcile such conflicting evidence, we investigated whether the degree of pre-experimental familiarity of items can be a factor that modulates the effects of repetition on source memory. In Experiment 1, we presented different groups of participants famous and nonfamous faces as pre-experimentally familiar and novel items. The experiment consisted of three successive phases: item repetition, item-source association, and source memory test. During the item repetition phase, a half of the famous or nonfamous faces were repeated eight times in a random order while participants were making male/female judgments. In the item-source association phase, both the repeated and the unrepeated faces appeared in one of the four locations on the screen one by one. Finally, during the source memory test, participants had to choose the location in which a given face was presented during the previous phase. As results, we found significant interaction between pre-experimental familiarity and repetition. Repetition impaired the location memory for pre-experimentally familiar items, while it led to greater memory accuracy for pre-experimentally novel items. We further replicated these results in Experiment 2, in which words and pseudowords were used as pre-experimentally familiar and novel items, indicating that the results are not specific to one type of stimuli. Taken together, our findings suggest that pre-experimental familiarity can modulate how repetition of an item affects the encoding and retrieval of detailed contextual information related to it, providing clues to elucidating how prior knowledge and new experience interact with each other to form episodic memory.

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26.313 Does memory enhancement training alter perceptual representations?

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Observers can learn statistical regularities and use them to hold more content in working memory (Brady, Konkle & Alvarez, 2009). Here we investigated whether this memory enhancement fundamentally alters the structure of perceptual representations as measured by a perceptual grouping task. Memory-Training Task: On each trial, 8 shapes were displayed, followed by a brief delay, and then observers reported the shape that had appeared at a cued location. Shapes were paired such that 80% of the time certain shapes co-occurred (e.g., 'shape A'-'shape B', 'shape C'-'shape D', etc.). After completing 8 blocks of 60 trials, observers nearly doubled the number of shapes they could remember (to 6.5 shapes). Perceptual-Grouping Task: Observers then performed three blocks of a color repetition detection task that is sensitive to perceptual grouping (Vickery & Jiang, 2009). On each trial, a row of alternating red and green shapes was presented, with one color-repeat along the row. Observers were instructed to detect the color repetition as quickly as possible and then report its location; the shapes were not task relevant and observers were instructed to ignore them.

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If trained pairs automatically form perceptual groups, then color-repeats within a pair should be more quickly detected than color-repeats across pairs. Additionally, to measure any pair-learning effects during the grouping task, we included a new set of "untrained pairs". In the first block, observers detected color-repeats faster when they occurred within pairs than between pairs for trained pairs (~51.2 ms difference, p=.02), but not for untrained pairs (p>.05). The within vs between difference for trained pairs was not present after the first block of test trials. Thus, learning arbitrary shape pairs through a memory training task affects performance in a basic perceptual task, suggesting that this training may give rise to fundamental changes in perceptual representations.

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26.314 **Object-based benefits without object-based representations.**

Sarah Cormiea[1](sarah.cormiea@gmail.com), Daryl Fougnie[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

The organization of visual information into objects strongly influences visual memory: Displays with objects defined by two features (e.g. color, orientation) are easier to remember than displays with twice as many objects defined by one feature (Olson & Jiang, 2002). Existing theories suggest that this 'object-benefit' is based on object-based limitations in working memory: because a limited number of objects can be stored, packaging features together so that fewer objects have to be remembered improves memory performance. This view predicts that memory for "packaged features" should be correlated (if you remember one feature of an object you should remember the object's other features). Counter to this prediction, we show that some object features are stored largely independently. Participants were instructed to remember the colors and orientations of 5 colorful isosceles triangles (five-object condition) or the color of 5 colorful circles and the orientation of 5 black isosceles triangles (ten-object condition). After encoding (1200ms) and retention (900ms), memory was assessed with a continuous report for both features. Critically, participants reported both features of the same item in the five-object condition, allowing us to determine whether features were stored in an integrated fashion. Here we replicate the object-benefit: participants remembered twice as many features when arranged in 5 versus 10 objects. However, in the five-object condition memory for the color and orientation of an object was largely independent—when participants failed to accurately report the color or orientation of an object they were often quite accurate at judging the object's other feature. These results challenge the claim that the object-benefit is driven by the storage of integrated object representations, and require a revision of the concept of object-based memory representations. We propose that working memory is object-based in regard to the factors that enhance performance, but is feature-based at the level of representational failure.

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26.315 **Attention and InformationTransfer from Visual Sensory to Visual Working Memory**

Jane Jacob[1](jjacob9@uh.edu), Shon MonDragon[1], Bruno Breitmeyer[1,2]; [1]Department of Psychology, University of Houston, [2]Center for Neuro-Engineering and Cognitive Science, University of Houston

Visual information first enters visual short-term memory through a brief sensory register (iconic memory) and is then transferred to a more durable visual working memory (VWM) store. Previous masking studies (e.g., Michaels & Turvey, 1979) indicate that transfer of items from iconic memory to VWM requires attention. However, it is unclear whether the same or separate attentional resources are called on for transfer into and for maintenance of visual information within VWM. The current experiment was designed to address this question. Observers were presented with an initial color display consisting of one, two or else three colors for 300ms.These displays, varying in load, were to be encoded in VWM for later comparison to a color probe. Each display was followed by an array of six letters for 10ms. Observers were first asked to report as many of the letters as possible, and then were shown the color probe and asked to indicate whether it was or was not shown in the initial color display. Results indicate separate attentional resources for transfer of information into and its maintenance within VWM. While increase of VWM load, as expected, decreased the total number of items that could be transferred into VWM, the increase in VWM load did not affect the rate of transfer from iconic memory to VWM. These findings develop the foundation for deeper explorations of information processing in visual memories. Michaels, C.F. and Turvey, M.T. (1979). Central sources of visual masking: Indexing structures supporting seeing at a single, brief glance. Psychological Research, 41, 1-61.

26.316 **Implicit memory representations in the oculomotor system**

Artem Belopolsky[1](A.Belopolsky@psy.vu.nl), Stefan Van der Stigchel[2]; [1]Vrije Universiteit Amsterdam, [2]Universiteit Utrecht

Humans tend to create and maintain internal visual representations of the environment that help guiding actions during the everyday activities. These representations range in their complexity from implicit memory to long-term memory. Recent studies have proposed that the oculomotor system might be critically involved in coding and maintenance of locations in memory. For example, saccade trajectories were found to curve away from a location kept in visual-spatial working memory. Furthermore, when participants were asked to memorize two locations, and then later select one location for further maintenance from that internal representation, saccades curved away from the ultimately remembered location. This suggests that the oculomotor system is flexibly used for coding to-be-remembered locations that are no longer present in the outside world. In the present study we investigated whether implicit memory representations are also rooted in the oculomotor system. Implicit memory representations are created without awareness as a result of a selection episode. To test this idea participants had to perform a simple task of making a saccade towards a predefined direction. On two-thirds of the trials an irrelevant distractor was presented unpredictably left or right from the fixation. On one-third of the trials no distractor was present. The results show that on the trials without a distractor, saccades curved away from the location that was occupied by a distractor on the previous trial. In a follow-up experiment this result was replicated and extended to cases when different saccade directions were used. In addition, we show that repetition of distractor location on the distractor present trials also results in a stronger curvature away. Taken together these results provide strong evidence that the oculomotor system automatically and implicitly codes and maintains locations that had been selected in the past, which biases future behavior.

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Perceptual organization: Shapes and objects

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

26.320 **Inhibitory mechanisms for visual form perception in the human visual cortex**

Adrian Garcia[1](adg772@bham.ac.uk), Shu-Guang Kuai[1], Richard Edden[2], Martin Wilson[5], Nigel Davies[5], Andrew Peet[5], Theo Arvanitis[4,5], Zoe Kourtzi[1,3]; [1]School of Psychology, University of Birmingham, UK, [2]The Johns Hopkins University, Maryland, [3]Laboratory for Neuro- and Psychophysiology, K.U.Leuven, Belgium, [4]School of Electronic, Electrical & Computer Engineering, University of Birmingham, UK, [5]Paediatric Brain Tumour Research Group, Birmingham Children's Hospital, UK

Successful visual recognition relies on our ability to extract structure from noisy sensory inputs, integrate local features into global forms and discriminate among similar objects. Previous neurophysiology studies have implicated inhibitory mechanisms in visual perception. However, the link between visual form perception and inhibitory mechanisms in the human brain remains largely unknown. Recent developments in magnetic resonance spectroscopy (MRS), enable the in-vivo measurement of low concentration metabolites such as the inhibitory neurotransmitter GABA in the human brain. Here, we investigated the relationship between GABA concentrations in visual cortex and human performance in visual form perception. We tested the observers' ability to discriminate radial and concentric global forms (Glass patterns). We manipulated a) the amount of background noise (coarse task), and b) the similarity between global forms, using linearly morphing between concentric and radial patterns (fine task). In addition, for each participant we collected spectroscopy data using a MEGA-PRESS pulse sequence that was optimised for GABA measurements. We collected single voxel (3cm3) MRS data in occipital cortex (covering early visual areas) and occipitotemporal cortex (covering higher visual areas anterior to retinotopic cortex). We correlated GABA measurements in these voxels with performance in the coarse (i.e. detection of global pat-

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terns in noise) and fine (i.e. discrimination of highly similar global patterns) tasks. Our results showed a significant positive correlation of behavioral performance with GABA concentrations in the early visual cortex for the coarse task while a negative correlation for the fine task. No significant correlations between behavioral performance and GABA concentrations were observed in higher occipitotemporal cortex. These findings suggest that the contribution of inhibitory mechanisms to human form perception is task-dependent. In particular, increased inhibition in early visual cortex may support form segmentation from noise, while decreased inhibition may support feature integration for the discrimination of global forms.

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26.321 **Visual adaptation to physical stability of objects**

Steven A. Cholewiak[1](scholewi@eden.rutgers.edu), Manish Singh[1], Roland Fleming[2]; [1]Psychology and Cognitive Science, Rutgers University, [2]Psychology, University of Giessen

Physical stability is an ecologically important judgment about objects that allows observers to predict object behavior and appropriately guide motor actions to interact with them. Moreover, it is an attribute that observers can estimate from vision alone, based on an object's shape. In previous work, we have used different tasks to investigate perceived object stability, including estimation of critical angle of tilt and matching stability across objects with different shapes (VSS 2010, 2011). The ability to perform these tasks, however, does not necessarily indicate that object stability is a natural perceptual dimension. We asked whether it is possible to obtain adaptation aftereffects with perceived object stability. Does being exposed to a sequence of highly stable (bottom-heavy) objects make a test object appear less stable (and vice versa)? Our test objects were vertically elongated shapes, with a flat base and a vertical axis of symmetry. Its axis could be curved to different degrees, while keep its base horizontal. The Psi adaptive procedure (Kontsevich & Tyler, 1999) was used to estimate the "critical curvature" - the minimum axis curvature for which the test object is judged to fall over. This was estimated in three conditions: baseline (no adaptation), post-adaptation with high-stability shapes (mean critical angle: 63.5 degrees), and post-adaptation with low-stability shapes (mean critical angle: 16.7 degrees). In the adaptation conditions, observers viewed a sequence of 40 distinct adapting shapes. Following this, a test shape was shown, and observers indicated whether the object would stay upright or fall over. Adaptation was "topped up" after every test shape. Most observers exhibited an adaptation to object stability: the estimated critical curvature was lower following adaptation to high-stability shapes, and higher following adaptation to low-stability shapes. The results suggest that object stability may indeed be a natural perceptual variable.

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26.322 **Meaning can be Accessed for the Groundside of a Figure**

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Does a first pass of processing access representations of more objects than will ultimately be perceived, with some later pruned by perceptual organization? Peterson and Skow (2008) showed that, "yes," representations at the shape level are accessed on the first pass of processing and suppressed if later pruned. We investigated whether conceptual knowledge is accessed for potential objects perceived as shapeless grounds. Subjects categorized words as natural or artificial. A novel silhouette preceded each word. Half the silhouettes suggested portions of familiar objects on their perceptually shapeless groundsides (Experimental silhouettes); these objects were either from a different superordinate category (natural vs. artificial) than the upcoming word; from the same superordinate category but a different subcategory (e.g., within natural, plants vs. animals); or the same object named by the upcoming word. The remaining silhouettes were Control silhouettes without a familiar object suggested on the groundside. Participants were slower to categorize words following Experimental than Control silhouettes when the object suggested on the groundside of the Experimental silhouette was from the same superordinate category but a different subcategory than the word (e.g., leaf/"deer;") than when they were from different superordinate categories (e.g., axe/"ant"; p <.05). Thus, conceptual knowledge regarding an object that is not perceived is accessed (e.g., the category plants for leaf) and facilitated, while other subcategories within the same superordinate category (natural objects) are suppressed. Therefore, responses are slowed to words from a different subcategory within the same superordinate category as the suggested object, but words from a different superordinate category are unaffected. No effects were observed when the suggested object and the word were identical; facilitated conceptual knowledge and suppressed shape representations cancelled each other. These results indicate that conceptual knowledge of potentially present but unperceived objects is accessed on a first pass of processing.

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26.323 **Figure-ground organization tested using a 3D shape constancy task**

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Conventionally, Figure-Ground Organization (FGO) has been studied by asking the subject to decide whether a 2D region in a picture looks more like a figure or ground. The main assumption behind these studies was that, from a computational point of view, FGO is a 2D operation. Two years ago we reported that performance in a FGO task was somewhat higher when the figure was perceived as a symmetric shape having volume. This was done by asking a subject to recognize the 2D shape of a figure or that of ground. In the present study we directly tested the role of three-dimensionality of a symmetric shape in FGO, by using a shape constancy task. If the observer perceives a given region in a stimulus as a figure (object), then she should be able to recognize the shape of the object. At the same time, we don't expect the observer to be able to recognize the shape of the background. In order to make sure that the subject is recognizing a 3D shape of an object, rather than a 2D shape of a region on the retina, we used shape constancy task. The observer memorized 3D shapes of two test stimuli in the first presentation and judged whether either of them was identical with the 3D shape of a stimulus in the second presentation. In "same" trials, the 3D shape was rotated around the vertical axis by a 20 deg angle. The stimuli were viewed binocularly. In one condition, the stimulus was perceived as a 3D symmetric "polyhedron". In the other condition, the stimulus was perceived as a 3D curve surrounding "empty space" between two polyhedral objects. Four subjects were tested. The results show that the performance with "polyhedron" is much better (d'=1.96) than with "empty space" (d'=0.79).

Acknowledgement: AFOSR, DoD, NSF

26.324 **Recognition of Amodal and Modally Completed Shapes by a Grey Parrot (Psittacus erithacus)**

Irene M. Pepperberg[1](impepper@media.mit.edu); [1]Department of Psychology, Harvard University

A Grey parrot, Griffin, previously taught English labels for various colors (red, blue, green, yellow, orange, purple) and shapes (regular polygons labeled "1-", "2-", "3-", "4-", "6-", "8-corner"), was tested on modal and amodal completion. Stimuli were primarily laser-printed paper shapes. For amodal completion, portions of variously colored regular polygons were occluded by black circles (which Griffin could not label) or other black polygons. Occasionally, occlusion resulted in a potentially confusing figure (e.g., triangle occluded by square to form trapezoid). Controls were colored polygons missing circular pieces and black circles appropriately displaced. For modal completion, Kanizsa figures were constructed using black 'pac-men' to form regular polygons on colored paper. Controls involved placing additional circles or 'pac-men' near the Kanizsa figure so Griffin could not simply count black objects. The principal investigator (PI) placed stimuli 15 cm from one of Griffin's eyes (distance determined as optimal in Pepperberg, Vicinay, Cavanagh, 2007), the other eye being focused on the PI; Griffin was then queried "What shape X?", where X was the color of the polygon in question. Griffin provided a vocal English shape label (using possible labels to 8). An undergraduate experimenter repeated Griffin's answer; only if her response matched the correct response was the parrot's label considered correct. Griffin received one trial per session, with sessions occurring 1-4x/wk, with breaks for student exam and intersession periods. Griffin's responses were very accurate (25/33 correct on Kanizsa figures; 20/24 correct for amodal completion; chance was 0.20). Results demonstrate that despite a somewhat different brain structure and considerably different visual system from that of humans, a Grey parrot solves at least two of the same visual cognitive problems faced by humans. (Supported by NSF grants 0920878, 1026256 to Ken Nakayama and The Alex Foundation)

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26.325 **Attention is allocated to figures only under conditions of uncertainty**

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It is widely assumed that attention is automatically drawn to figures, which, if true, would have important implications how attention functions. Nelson and Palmer (2007) found support for this assumption using displays in which a central border divided a rectangle into two equal-area regions and the familiarity of an object sketched on one side of the central border served as the sole figural cue. They found faster, more accurate, responses to targets on the familiar side of the central border rather than the complementary side. If attention is automatically drawn to figures, similar results should be obtained under different presentation conditions. Nelson and Palmer used large displays (18° x 20°), and high spatiotemporal uncertainty regarding the target (12 potential locations, and 0, 150, 250, or 500-ms SOAs). Using smaller displays (5.3° x 5.5°) and lower spatiotemporal uncertainty (4 target locations, 80-ms SOA), we failed to observe evidence that attention is automatically drawn to figures, $p > 0.6$, although we replicated their effects when we used large stimuli (14° x 20°) with variable SOAs and target locations like theirs, $p < .05$ (VSS 2011). This year we tested whether subjects adopt a strategy of attending to the familiar configuration under conditions of high target spatiotemporal uncertainty by using the same large displays but lower spatiotemporal uncertainty (4 target locations and an 80-ms SOA). We failed to find any evidence of an attentional advantage for figures in either accuracy or RTs, ps > 0.16. The difference in response patterns in the two experiments with different spatiotemporal uncertainty was significant, $p < .04$. Our results indicate that attention is not automatically drawn to figures. Instead, it is strategically deployed to familiar figures under conditions of high spatiotemporal uncertainty. The question remains whether this strategy applies to all figural cues or only to familiarity.

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26.326 **The window of 'postdiction' in visual perception is flexible: Evidence from causal perception**

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One of the most counterintuitive effects in perception is postdiction — the ability of the visual system to integrate information from shortly after an event occurs into the perception of that very event. Postdictive effects have been found in many contexts, but their underlying nature remains somewhat mysterious. Here we report several studies causal perception that explore whether the temporal extent of the postdiction 'window' is fixed, or whether it can flexibly adapt to different contexts. Previous work has explored a display in which one disc (A) moves to fully overlap a second disc (B), at which point A stops and B starts moving. This 'full-overlap' display will often be seen in terms of non-causal 'passing', wherein A is seen to pass over a stationary B (even when their colors differ). However, when a third 'context' object (C) begins moving in the same direction as B at roughly the same time, the full-overlap event will often be perceived as causal 'launching', wherein A collides with B, causing it's motion. These percepts can be influenced postdictively, when C begins moving slightly after the A/B overlap. By varying the objects' speeds, we were able to determine whether the duration of the postdiction window is a constant, or whether it varies as a function of an event's pace. The results clearly demonstrated that the postdiction window is flexible, and in a surprising way. The existence of a postdictive effect was a function not just of the temporal offset (between when B and C started moving) but also of a spatial offset — how far B had moved before C started moving, largely independent of the timing. This suggests that the visual system is adapting to the speed of the stimuli and adjusting the extent of the postdiction 'window' accordingly.

26.327 **Negative parts and local reversal of figure and ground**

Seha Kim[1](sehakim@eden.rutgers.edu), Manish Singh[1], Jacob Feldman[1]; [1]Department of Psychology, Center for Cognitive Science, Rutgers University - New Brunswick

Deep indentations in shapes are often perceived as negative parts, i.e., as regions "subtracted" from a base shape (such as a bite taken out of an apple; Hoffman & Richards, 1984). Previous work (Kim & Feldman, 2009) has shown that figure/ground (f/g) assignment can reverse in the vicinity of a negative part. Here we study the conditions that favor such a reversal and provide a mathematical framework for understanding it. We constructed shapes by cutting a narrow strip out of one side of an elongated elliptical base shape. In principle, the resulting contour can be perceived as a single object with a complex shape or as a very simple object (the elongated shape) from which a second shape (the strip) has been subtracted, in which case f/g tends to reverse within the strip so that the indentation is perceived as a figure. We used the motion-probe task, which assesses local border ownership, placing probes both within and outside the indentation. We manipulated the smoothness of the corner between the base shape and the indentation, and found a systematic effect of smoothing: within the indentation, but not outside it, there was a tendency towards local f/g reversal which was maximal when the junction formed a sharp corner and diminished monotonically as the corner was increasingly smoothed. We interpret this smoothing effect within a probabilistic framework in which the two interpretations, one complex shape vs. a simple shape with a negative part (i.e., a combination of a two shapes with a f/g reversal), compete via a principled Bayesian comparison. The model can accommodate a broad range of shape manipulations, in all cases showing how local variations in f/g assignment result from the selection of the most probable (maximum posterior) or, equivalently, simplest (minimum description length) shape interpretation.

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26.328 **Impaired shape integration but normal illusory contour formation in schizophrenia: Evidence for a high-level grouping deficit**

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Background. Electrophysiological studies have shown that people with schizophrenia are impaired at processing Kanizsa shapes (Foxe et al., 2005; Spencer et al., 2004), but the level at which this integration problem occurs is unclear. Does the problem owe to a poor representation of global shape, or can it instead be attributed to a more basic dysfunction in interpolating between locally relatable edges? Method. We addressed this question behaviorally by testing 18 clinically stable patients and 13 healthy controls on a "fat/thin" discrimination task (Ringach & Shapley, 1996). On each trial, a computer monitor briefly displayed four sectored circles ("pac-men"). In the "illusory" condition, the pac-men were oriented to form an illusory square and the task was to determine whether the square was "fat" or "thin". In the "fragmented" condition, the pac-men pointed downward, and the task was to indicate whether they were all rotated left or right. Half of the trials in each condition incorporated distractor lines, which are known to disrupt illusory contour formation. Performance was assessed with an entropy-based Bayesian adaptive staircase; threshold corresponded to the amount of pac-man rotation needed to achieve 80% accuracy. Results. Across all subjects, distractor lines raised thresholds more in the illusory condition than in the fragmented condition ($p=.004$). This interaction did not depend on participant group ($p=.78$), suggesting that patients and controls filled-in illusory contours comparably. Crucially, patients were worse than controls at discriminating illusory shapes ($p<.004$) and were the same as controls at discriminating fragmented configurations ($p>.11$). This interaction was significant ($p=.04$). Conclusion Illusory contour formation is intact in schizophrenia, but global shape integration is not. Patient impairments in representing objects from fragmented information may result from relatively high-level visual processing deficits.

26.329 **When topological change diminishes visual masking**

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Visual masking refers to a phenomenon that a briefly presented stimulus (target) could be rendered less visible or totally invisible by the presentation of a second stimulus (mask). Evidence shows that similarity between target and mask enhances masking effect, but in a selective way. Specifically, similarity in one visual property deteriorates the target perception on this property but leaves masking for other properties unaffected. Here we show that similarity based on topological property (e.g. the number of holes) has distinctive effect on masking. We manipulated the topological similarity

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between target and mask and investigated the topological similarity effects in both topology-relevant (i.e. discriminating between no-hole and one-hole stimuli) and irrelevant (e.g., discriminating color) tasks. We found that topological similarity affected masking not only of the topological property itself but also of other properties, while the similarity of non-topological properties (e.g. color and shape) only affected masking of the properties themselves. This trend also existed when we used one-hole and two-hole stimuli to represent topological difference. The potential confounding such as luminous flux and shape, which might co-vary with topological manipulations, could be ruled out by adopting area-matched stimuli and the further analyses revealing no effect from shape difference when target and mask had the same topological property. Our results suggest that topological property has precedence over other properties in visual processing, and masking effect might be divided into two levels: feature level (e.g., color and shape) and object level which is determined by topological property.

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26.330 Shape Similarity Judgments Under Conditions of Uncertainty

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Shape similarity judgments involve more than immediate perception. Prior experience and attentional biases may also be important. We investigate these issues using 2D contour shape triplets generated by morphing two novel "parent" shapes into a third "daughter" shape that is, by this measure, equally similar to both parent shapes. Participants were presented with shape triplets and judged which parent shape was more similar to the daughter shape. Each of 100 triplets was presented twice per session (e.g., the triplet presented on trial 1 was repeated on trial 101), on each of 4 sessions (days 1, 2, 8, & 31). Consistency of responding (the probability of choosing the same parent shape on two different presentations of the same triplet) was measured. Despite objectively equivalent similarity, average consistency was above chance and approximately equal within and between sessions (0.70 vs. 0.71). Since between-session intervals were much longer (1-30 days) than within-session intervals (<15 minutes), equivalent performance suggests participants weren't basing future responses on explicit memory of earlier choices. Next, for each participant, we selected consistent-response triplets from each session, and measured response consistency for these triplets in all other sessions. Average consistency was higher (0.78) and independent of the session from which the shapes were selected and the session on which consistency was measured. This result agrees with a model in which individual participants respond consistently to some shapes and not others. Finally, doing the same analysis using consistent-response triplets from different participants (e.g., measuring consistency in subject A using consistent-response triplets from subject B) had little affect on consistency, indicating that different participants responded consistently to different subsets of the triplets. Together, these results suggest that individualized, stable attentional biases drive judgments of similarity under conditions of uncertainty.

26.331 A Temporal Window of Facilitation in the Formation of Shape Percepts

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The human visual system must extract reliable shape information from cluttered visual scenes several times per second, yet the nature of the underlying computation remains poorly understood. Here we probe the dynamics of this process to estimate time constants that might provide clues to the underlying neural circuit. We employed a repetitive-presentation shape discrimination paradigm. On each trial, one or two instances of a single-frame (10msec) stimulus presentation were embedded in a continuous dynamic noise sequence consisting of randomly positioned and oriented line segments. Each stimulus frame consisted of a target contour, also embedded in random line segment noise. With 50% probability the target contourwas either a) an animal shape or b) a "metamer" shape. Animal shapes were line segment sequences approximating the boundaries of animal models. Metamer contours were line segment sequences with the same first-order statistics as the animal shapes, but random higher-order statistics. In the two-stimulus-frame condition, the same shape was used in both stimulus frames. The inter-stimulus interval (ISI) was varied, ranging from 0 msec to 100 msec. QUEST was used to measure the threshold number of distractor elements in each frame, for 75% correct shape discrimination. We found a significant facilitation of shape discrimination for two stimulus presentations compared to a single stimulus presentation. Interestingly, discrimination performance varied systematically and significantly as function of ISI (for 4 of 5 subjects), peaking at roughly 50 msec delay between the two stimulus frames. These results suggest a narrow temporal "window of opportunity" in which shape processing can be optimally reinforced. The fact that facilitation is not monotonic as a function of time excludes both iconic memory decay and probability summation as simple explanations for our results. The timing of the facilitation may instead reflect the time course of the recurrent processing underling rapid visual shape computation.

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26.332 Systematic differences in perceptual salience among different types of nonaccidental properties

Eric Weismantel[1](weismantel.2@buckeyemail.osu.edu), James T Todd[1], James C Christensen[2]; [1]Ohio State University, [2]Air Force Research Laboratory

Previous research has demonstrated that changes in nonaccidental properties such as cotermination or parallelism are more easily detected than changes in purely metric properties such as object length (Biederman & Bar, 1999). Nonaccidental properties are especially useful for object recognition because they remain relatively stable over different vantage points. However, some of these properties are more stable than others (Chen, 2005), and the present research was designed to investigate whether this has any influence on their relative perceptual salience. Observers performed a match-to-sample task for 2D shapes in which they were required to detect a change in the cotermination of edges (a topological property), a change from straight to curved edges (a projective property), a change from parallel to non-parallel edges (an affine property), or a change in object length (a purely metric property). The results revealed that discrimination thresholds varied systematically among the different types of shape changes. Changes in the pattern of cotermination were the easiest to detect, followed by differences between straight and curved edges, and differences between parallel and nonparallel edges. Purely metric changes in object length produced the highest thresholds of all. We also examined several possible metrics for scaling the differences between object shapes in an effort to determine if any of them are predictive of human performance. These included the correlation or Euclidean distance between pixel intensities or wavelet responses, and a maximum displacement measure originally proposed by Hausdorff. The Hausdorff metric provided the best overall fit to the data, but none of these measures can explain the systematic differences among the different types of shape change.

Acknowledgement: NSF grant BCS-0962119

Spatial vision: Models

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

26.401 Nonadditivity of stochastic and deterministic masks: suppression may contaminate estimates of equivalent noise

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Masking from 2D white noise is typically attributed to an increase in variance in the detecting mechanism. Direct evidence for this comes from the double pass technique, in which noise masks increase the consistency of observers' responses (albeit by less than expected). But noise masks must also activate non-target mechanisms, and these will have a suppressive effect on the detecting mechanism similar to that of cross-oriented grating masks. A consequence of this gain control suppression is that masks should attenuate the perceived contrast of targets. We demonstrate this using a 2IFC matching paradigm for 1c/deg horizontal log-Gabor targets embedded in either white noise or an oblique mask of three times the target frequency (3F mask). What was previously unknown is how the two contributions to masking – variance and suppression – interact with each other. We assess this here by jittering the contrast of a zero-mean pedestal on a trial-by-trial basis (e.g. Cohn, 1976, J Opt Soc Am, 66: 1426-1428), producing a noise stimulus that is entirely within-mechanism. We measured masking functions using a 2IFC procedure for this jitter mask with and without cross-orientation suppression from a high-contrast 3F mask. Arguably, the effects of these different masks might be expected to sum. However, the standard gain control model predicts that when one source is more potent than the other, it will dominate, accounting for all of the masking. At low jitter variances, the 3F mask raised thresholds fourfold for all three observers. At higher jitter variances the masking functions converged, as predicted by the model. However, since masking by suppression and masking by variance produce identical forms of masking function, it is not possible to use (noise) masking functions to assess the equivalent internal noise unless the relative contributions of each source of masking are known. This might be difficult to achieve.

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26.402 **Using Repeated Noise to Look Inside the Box**

Stanley Klein[1](sklein@berkeley.edu), Thom Carney[1], Hairan Zhu[1], Sean Bupara[1]; [1]School of Optometry, UC Berkeley

The use of noise has been a powerful tool in learning about nonlinear stages of visual processing. We have extended the approach of Petrov, Dosher & Lu (2005, 2006) to enable us to gather more accurate data and extend their analysis in a manner that enables us to isolate stages of processing. Petrov measured Gabor orientation discrimination in periphery with added oriented noise. Observers reported target Gabor orientation (left/right) for several target contrasts in the presence of oriented noise background that was congruent or incongruent with the target orientation. In our experiments the following modifications were made: noise orientation never shifted, we included zero contrast Gabor stimuli for classification images, confidence ratings as well as orientation ratings were given, the same noise was typically used for the two locations and two target orientations and across different runs. Otherwise in a single run different noise was used. The purpose of using the same noise repeatedly in randomized order was to gain accurate responses with small variability. The repeated noise across locations, orientations and runs enabled d' and bias to be calculated for each noise sample, giving the following results and conclusions: 1)One surprising finding was that d' and bias were very different in the two peripheral locations in 4 of the 5 subjects. 2)The orientation/confidence ratings reveal nonlinearities and a jaggedness cue that eliminated the simple model proposed by Petrov et al. 3)Repeated noise across runs revealed factors that changed during perceptual learning, the original goal of the study. 4)Decision stage weights could be shown to be different for different noise samples, a powerful addition for studies using noise. Another difference from the original Petrov et al. results was that by our reaching asymptotic behavior after learning, the filter weights for the congruent orientation were much weaker than for the incongruent orientation.

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26.403 **A model of target detectability across the visual field in naturalistic backgrounds**

Chris Bradley[1](cbradley@math.utexas.edu), Wilson S. Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Rigorous analysis of behavior and physiology in most natural tasks requires first characterizing the variation in early visual processing across the visual field. We describe a model of target detectability in uniform, naturalistic, and natural backgrounds. For detection in uniform luminance backgrounds, the model reduces to a physiological model of retinal processing that includes the optical point spread function, a sampling map of P ganglion cells, a difference-of-Gaussians model of ganglion cell processing, and a near-optimal pooling function over ganglion cell outputs. Parameters for this retinal component of the model were either fixed from anatomy and physiology or estimated by fitting the detection thresholds reported for the set of stimuli used in the ModelFest1 project. For detection in noise or natural backgrounds, the model adjusts the predicted contrast detection thresholds of the retinal processing component using a known empirical relation: the square of the threshold in white and 1/f noise backgrounds is proportional to the square of the background noise contrast plus an additive constant. This additive constant equals the square of the threshold on a uniform background, which is the prediction of the retinal processing component of the model. In the model, masking (the slope of the above masking function) depends on both the contrast power of the background that falls within the critical band of the target, and on a more broadband contrast gain control factor. The model has been implemented efficiently so that predictions can be generated rapidly for arbitrary backgrounds, target locations, and fixation locations. The model works well at predicting contrast detection thresholds across the visual field in uniform and naturalistic noise backgrounds, for targets similar to those used in the ModelFest project, but remains to be tested on natural backgrounds. 1 Watson & Ahumada (2005) Journal of Vision, 5, 717-740.

26.404 **Mach bands and models of spatial vision: the role of 1st, 2nd and 3rd derivative operators in encoding edges and bars**

Mark Georgeson[1](m.a.georgeson@aston.ac.uk), Stuart Wallis[1]; [1]School of Life & Health Sciences, Aston University, Birmingham, B4 7ET, UK.

In the 1860s Ernst Mach observed that light or dark bands could be seen at abrupt changes of luminance gradient, in the absence of peaks or troughs in luminance. Mach bands have been important for theories of visual feature coding, because they suggest that bars or lines are found at peaks and troughs in the output of even-symmetric spatial filters, such as the Gaussian second-derivative. Our experiments showed that the probability of seeing Mach bands was nearly independent of the contrast (20-80%), duration (50-300 ms), and spatial scale of the ramp-edge luminance waveform, but increased with the relative sharpness of its 'corners'. These results rule out the idea that Mach bands depend simply on the amplitude of the second derivative, but we develop a multi-scale model, based on Gaussian first- and second-derivative filtering incorporating automatic scale selection (Lindeberg, 1998), that can account accurately for both the perceived structure of the bands and the probability of seeing them. A key idea is that Mach band strength (probability) depends on the ratio of second- to first-derivative responses at the peaks in the second-derivative scale-space map. This ratio is contrast-invariant, nearly scale-invariant, and increases with the sharpness of the 'corners' of the ramp – all as observed. Our observers also marked the perceived positions of the bands and the edges of the bands. We find that the edges of Mach bands pose a difficult challenge for models of edge detection. But if the second-derivative output is subject to a smooth, threshold-like nonlinearity (power function, exponent p=3) then differentiated again, the peaks in this nonlinear third-derivative response predict the locations of Mach band edges strikingly well. Mach bands thus shed new light on the multiscale filtering systems of human spatial vision.

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26.405 **Simple line-length estimation not so simple**

Kyriaki Mikellidou[1](k.mikellidou@psych.york.ac.uk), Peter Thompson[1]; [1]University of York, United Kingdom

Mamassian & de Montalembert (2010) made direct comparison between the vertical and horizontal components of simple figures, an inverted 'T', a horizontal 'T', an L-shape and a cross. They proposed a model suggesting two components, anisotropy which makes a vertical line look 6% longer than a horizontal and a bisection effect which makes a bisected line 16% longer. At VSS (2011) we reported a study of the Oppel-Kundt illusion in which we did not find any bisection effect. We have now examined anisotropy and bisection effects in separate experiments. Comparing the lengths of simple vertical and horizontal lines we find that verticals are perceived to be 7% longer, a figure close to that of Mamassian & de Montalembert. We have extended our observations to the same group of figures matching only components of the same orientation. Our results show no evidence for Mamassian's bisection component. Rather we propose a 3-component model to explain line-length estimation in these simple figures: anisotropy, abutting and crossing. Abutting occurs when the end of one line touches another. We used the method of constant stimuli to generate psychometric functions from which PSEs were determined. We varied the length of a vertical or horizontal comparison line between 5.2-7.0 degrees of visual angle in a single interval 2AFC judgment. In an experiment comparing the vertical line in an inverted 'T' figure with a vertical comparison line, the former was judged 9% longer by virtue of this abutting effect. In an experiment to compare the vertical line in a cross figure with a vertical comparison line, the former was judged to be 7% shorter by virtue of the crossing effect. Finally, we confirmed our model by testing additional simple figures, such as the horizontal 'T' and L-shape.

Acknowledgement: A.G. Leventis Foundation

26.406 **Spatio-temporal characteristics of a rotating segmented ring.**

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The purpose of this study was to identify the optimal characteristics of a rotating segmented ring in a single subject design. The black and white segmented target optotype on a gray background had a 20.25mm diameter with 9 levels of thickness (4–20% of diameter), 3 levels of segmentation (4,6,8) and 10 levels of rotation (10-100RPM). Primary outcome was the distance to detect the target. Target was presented on a 17" monitor with 75hz refresh rate between two other rotating optotypes with the same characteristics, but 5% larger and smaller. The subject moved forward until he could see the target and the larger optotype, but not the smaller. Distance was correlated with number of segments (r=.87), thickness (.345), segment area (.758), and RPM (-.248). In a stepwise linear regression (R2=.94) distance = 6.8(feet) + 2.3*segment length + 2.8*thickness - .14*RPM (all p<.001). Analysis of residuals yielded a quadratic effect of RPM (R=.13, p=.25, optimal 35RPM), quadratic effect of # segments (R=.12, p=.29, optimal 6-7 segments), cubic effect of thickness (R=.50, p<.001, optimal 10% of diameter). Only the effect of thickness demonstrated a statistically significant deviation from a linear relation between the optotype characteristics and threshold distance. The number of segments and RPM graphically supported an optimal relationship that should be tested with more levels and subjects. In conclusion, the ability to detect a rotating, segmented ring is not a simple acuity task based on a linear function of the size of the segments.

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26.407 **The Adaptive Psi Method and the Lapse Rate**

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As originally proposed, the adaptive psi method (Kontsevich & Tyler, 1999, Vision Research, 39, 2729-2737) requires that a specific value for the lapse rate is assumed, resulting in bias in parameter estimates when the generating lapse rate does not match this assumed value. However, we may free the lapse rate parameter if we subsequently fit results in a separate procedure. Unfortunately, this strategy also results in a significant bias in parameter estimates (Prins, VSS, 2011; doi:10.1167/11.11.1175). Here, I test two modifications to the original psi-method. In the first (and most obvious) modification, the parameter space across which the psi-method calculates the posterior probability distribution (in which it attempts to reduce uncertainty) was extended to include the lapse rate (as well as the threshold and slope) parameter. The second modification of the psi method combined trials in which stimulus placement was controlled by the original psi-method with a (smaller) number of trials which placed stimuli at an asymptotically high level of performance. Results were then fitted in a separate procedure using a maximum likelihood criterion. The behavior of both of these modifications was tested using computer simulations, as well as human observers. While parameter estimates obtained using the first modification did eventually converge on the generating parameter values without bias, the number of trials required to reach convergence would, in most practical cases, be prohibitive. Moreover, trial runs frequently contained long series (often consisting of more than a hundred) of consecutive stimulus placements near asymptotic levels of performance. Considering both the degree of bias and the efficiency of estimation, best results were instead obtained using the second modification of the psi-method in combination with the fitting of a model which assumed that any incorrect responses observed for the trials placed at the asymptotic stimulus intensity were due exclusively to lapses.

Spatial vision: Crowding

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

26.408 **The visual system obligatorily integrates information over a greater spatial extent when attention is divided**

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The visual system's tendency to represent summary statistical information from crowds of objects has been well documented in recent research. However, this property of the visual system has the potential to provide insight into other visual phenomena as well. In the current set of experiments, we tested whether orientation information is automatically integrated across a region of space, and whether the spatial extent of integration depends on the allocation of attention. On each trial, observers saw either a single cue, which reliably directed observers to the visual field where a stimulus would appear, or saw two cues (one in each visual field), which revealed no stimulus location information. Observers then viewed a set of three oriented gabors (2 flankers, 1 target arranged horizontally) for 70 ms in either the left or right visual field, and were asked to adjust a test gabor to match the perceived orientation of the center target. Both flankers were 15 degrees clockwise or counterclockwise relative to the center target. In the single cue condition (reliable), observer adjustment to the center target was more precise than in the two-cue condition. Remarkably, in the two-cue condition, observer adjustment closely matched the average orientation of all three gabors. Modeling analyses revealed that this shift towards the mean reflected integration (i.e., averaging) of the three stimuli, and not substitution (i.e., incorrectly reporting a flanker). These results suggest that the size of the crowding region, or the integration field, is malleable and critically dependent on one's attentional strategy. While attentional effects on the size of integration fields have been shown previously, the present results are the first to reveal attentional effects on the extent of integration, and also reinforces the link between crowding and summary statistical representations.

Acknowledgement: NSF

26.409 **Crowding is consequence of attentional failure**

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Introduction: Crowding occurs when objects are too close together and features from several objects are combined into a jumbled percept. Two classes of mechanisms have been proposed: those involving purely perceptual factors and those pointing to a limited spatial resolution of attention. To test the attentional resolution hypothesis, we recorded ERPs and measured the N2pc component—an index of focused attention—and the SPCN component—an index of visual working memory. If crowding reflects a failure of attention, then N2pc should be reduced under conditions of crowding. Participants and methods: Thirteen healthy young adults participated in this study. Two arrays of three letters were presented, one on each side of fixation. One array was red and the other was green. Observers were told to attend either to the red array or the green array and to report whether the central letter of the attended array was a vowel or a consonant. Crowding was manipulated by using three distances between the target and the surrounding non-target letters: near, intermediate and far. The stimulus duration was 200 ms, with an SOA of 1600–1800 ms. Results: We found significant differences in the correct response rates and RTs depending on the level of crowding, with better performance (fewer errors and shorter RTs) as the distance between the target and nontarget letters increased. The key result was that the N2pc was virtually eliminated when the nontargets were near the target, indicating that attention cannot be focused onto the target under conditions of crowding. Interesting, the SPCN was largest under conditions of crowding, suggesting that observers stored all three items in working memory when the target could not be selected via attention. Conclusions: These findings suggest that crowding is a consequence of attentional failure and that working memory is recruited when selective attention fails.

Acknowledgement: NIH R01MH076226, MECESUP-Chile, VRAID-PUC, Becas Chile-CONICYT

26.410 **Crowding of parafoveal targets without focal attention**

Laura Renninger[1](laura@ski.org), Saeideh Ghahghaei[1,2]; [1]Smith-Kettlewell Eye Research Institute, [2]Goldsmiths, University of London

MOTIVATION When moving our eyes in the real world, the relative arrangement of objects with respect to the fovea is always changing. A target that was crowded radially could be crowded tangentially after a saccade. In this work, we examine to what degree crowding occurs in the parafovea when attention is divided between two potential target locations within a given hemifield, and whether it retains radial-tangential asymmetries. METHODS Target was an oriented gabor located in one of two locations that were positioned in the upper, lower, left or right hemifield with respect to fixation. Both target-present and target-absent locations were flanked with plaids, oriented radially or tangentially in the crowded conditions. No flankers were present in the baseline condition. Similar to previous studies (Petrov & Meleshkevich, JOV 2011), spatial frequency, target-distractor spacing and gabor size were simultaneously manipulated with an adaptive staircase to determine Gabor period threholds (Kontsevich & Tyler, Vision Research 1999). Subjects responded whether the target was tilted left or right, regardless of location. We tested eccentricities of 2.12 – 3.54deg which correspond to distances at which a 3-5 degree saccade would rotate distractors 90degrees about a target (i.e. from the radial to tangential position). RESULTS Crowding factors ranged from 0 to 1.2 for radial configurations and 0 to 0.6 for tangential configurations. Although idiosyncratic across the visual field and observers (see Petrov & Meleshkevich, Vision Research, 2011), on average the crowding asymmetry held for our 3 participants and was most pronounced in the lower and left hemifields. CONCLUSION In conditions of non-focal attention across a hemifield, crowding exists in the parafovea and on average, exhibits radial-tangential asymmetry similar to that for more eccentric targets. Naturally occurring saccades tend to be about 4 degrees in amplitude and we speculate that they may serve to "de-crowd" parafoveal stimuli.

Acknowledgement: NIH R01 EY018004-06

26.411 **Presaccadic Foveal Priming Diminishes Crowding**

Benjamin Wolfe[1](bwolfe@berkeley.edu), David Whitney[1]; [1]Department of Psychology, University of California at Berkeley

Visual crowding is the reduction of one's ability to identify or describe a target without fixating on it in the presence of flanking stimuli. The degree of target-flanker separation limits the amount of information that can be acquired from peripheral visual input [Bouma, 1970]. More recent research has shown that presaccadic shifts of spatial attention alone do not attenuate crowding [Morvan and Cavanagh, 2011], although similar presaccadic shifts of attention are known to improve task accuracy with uncrowded targets [Deubel and Schneider, 1996]. Here we tested whether a presaccadic foveal prime of a peripheral crowded target would improve recognition when saccades were directed to the target. In our experiment, two crowded letter arrays were presented gaze-contingently, one of which contained a target letter. On each trial, subjects chose to saccade to one of the two arrays. We found that saccades made to the array that contained the target resulted in improved target recognition when subjects were presented with a brief (50 ms) prime prior to the saccade. The prime only improved accuracy when subjects made a saccade to the array that contained the target. The effect required that the prime contain salient information about the crowded target stimulus, and it required a saccade to be executed. In addition, there was no effect of saccades on target identification without a prime or with an invalid prime. The foveal information available from the valid prime facilitated target identification in the periphery, indicating that presaccadic feature-based attention to a crowded target can be manipulated to diminish crowding.

Acknowledgement: NSF-GRFP

26.412 **Presenting a target and its surrounding flankers in different eyes reduces visual crowding, even though eye of origin difference is imperceptible**

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Perceptual distinction between a peripheral target and its surrounding flankers is known to relieve the target from visual crowding. This distinction can be caused by color, depth, shape, luminance, size, contrast polarity, spatial frequencies, motion, and contrast. It has also been reported that crowding is not affected by whether the target and flankers are presented in the same or different eyes (Levi 2008). However, in a task to discriminate the orientation of a letter C, whether it is in its normal or 180 degree rotated version, we found that crowding was substantially reduced when the flanking Os were in a different eye from the target, for both 4 and 8 flankers, in all three observers tested. Observers reported that they could not tell whether all items were in the same eye. However, such a relieve from crowding by dichoptic presentation was not apparent when the task was to identify the orientation of a letter T flanked by four other Ts, each randomly oriented in one of four possible orientations (see also Kooi, Toet, Tripathy, and Levi 1994). We suggest that the relieve from crowding was achieved by a more salient target under dichoptic presentation, making the target more easily selected by exogenous attention and thereby decoded in subsequent visual processing. According to the V1 saliency hypothesis (Li 2002), the saliency of any location is determined by the highest V1 neural response to it. An eye of origin singleton target becomes salient when the flanking Os suppress each other more strongly than they do to the target, due to V1's intra-cortical suppression that is eye of origin selective (DeAngelis, Freeman Ohzawa 1996, Zhaoping 2008). However, collinear facilitation between V1 neurons responding to various bars in the Ts may interfere with intra-cortical suppression to make the saliency mechanism effective.

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26.413 **An early cortical suppression might contribute to crowding**

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Although crowding has been studied extensively with visual psychophysics for many years, its neural mechanism, especially when and where crowding occurs in the brain, remains elusive. Here, we tapped into this question using event-related potentials (ERPs). A target was centered at 8° eccentricity in the upper-left visual quadrant, either alone or with two flankers positioned radially. Both the target and flankers were a circular patch of a sinusoidal grating. We changed the center-to-center distance between the target and flankers to manipulate the magnitude of crowding effect. In the near flanker condition, the distance was 2.48°. In the far flanker condition, it was 5.07°. Only in the former condition, there was a significant crowding effect as manifested by orientation discrimination impairment with the target, consistent with Bouma's law of crowding. We measured the earliest ERP component (C1) evoked by five stimulus configurations, including the target only, the target with the near flankers, the target with the far flankers, the near flankers only and the far flankers only. The C1 had a peak latency of about 80 ms and is believed to be generated in early visual cortical areas (e.g. V1 and V2). We found that, the sum of C1 amplitudes evoked by the target and the far flankers only was equal to the C1 amplitude by the target with the far flankers. However, the sum of C1 amplitudes evoked by the target and the near flankers only was significantly smaller than the C1 amplitude by the target with the near flankers, indicating a cortical suppression between the target and flankers. Notably, the suppression was not found when subjects' attention was directed away from the stimuli. These results suggest that the early cortical suppression enabled by spatial attention might contribute to the crowding effect.

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26.414 **Perceptual Crowding in a Neural Model of Feedforward-Feedback Interactions**

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Problem. The orientation of peripherally presented items is more difficult to recognize when surrounded by other items with similar features. This phenomenon is called ''crowding'' (Levi, Vis.Res. 48, 2008, Whitney & Levi, TiCS 15, 2011). Despite the large body of literature on crowding, only few quantitative models exist that can reproduce psychometric curves referring to varying target contrast or target-flanker spacing. Model. We propose a model of feedforward and feedback processing in visual cortical areas V1 and V2 for robust contour grouping and feature detection (Weidenbacher & Neumann, PLoS ONE 4, 2009). The model incorporates an additional stage of center-surround normalization for pooling oriented contrasts and grouping responses. Results. We employ input configurations with oriented bars and perturbed them by additive Gaussian noise similar as in van den Berg et. al. (PLoS Comput. Biol. 6, 2010). When varying the target contrast and target-flanker spacing we observed a quantitatively good match with psychometric curves derived from human experiments. But in contrast to previous modeling investigations our approach also predicts that crowding is partially released, when the surrounding flankers form a contour. This effect is explained by the enhancement of elongated contours in the recurrent loop of boundary integration. The enhanced activity and the greater extent of an elongated contour results in an increased inhibition at the final pooling stage which in turn reduces the crowding effect of surrounding flankers (configuration effect). Conclusions. The proposed model provides further evidence for the role of feature integration along the feedforward sweep of processing that is supported by stages of lateral boundary integration and modulating feedback in target detection and object recognition processes. The integration of context relevant features leads to context-sensitive increase in activity that counter-acts the impact of crowding and, thus, acts like an attentional gating at different stages of cortical processing.

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26.415 **Jiggling the crowding away: improving letter recognition in peripheral vision**

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Object recognition can be unfavorably affected by placing other objects nearby. This crowding phenomenon is a major limiting factor in peripheral letter recognition. Previous studies (e.g. Macedo et al., 2008; Rosenberg et al, ARVO2011) showed a connection between retinal image motion and enhanced isolated target recognition. Here, we examine how adding motion cues such as jiggling motion influences the effect of crowding on letter recognition in peripheral vision. "Jiggling" is defined as a rapid displacement along a specified direction with a fixed magnitude, repeated at a given temporal frequency. We examined four configurations of jiggling motion: target motion only, flanker motion only, the same motion in both the target and flankers, and two orthogonal motions applied to the target and flankers, respectively. Five normally sighted adults participated. Strings of three random letters with 1° print size (corresponding to 100% accuracy of isolated letter recognition) and standard spacing (1.16×x-width) were presented at 10° eccentricity on the right or left of a fixation point for an exposure duration of 188ms. For each motion configuration, we measured accuracy for identifying the middle letters for two motion directions (horizontal and vertical), two temporal frequencies (47 and 94ms/cycle), and three levels of motion amplitude (0° (stationary), 0.1°, and 0.2°). Averaged across observers, letter recognition accuracy was 54% for the stationary condition. Accuracy increased to 76% ($p<0.0005$) when motion was applied to the target only (irrespective of motion direction, amplitude, and frequency), and remained the same for the three other motion configurations (mean accuracy=52%). A control experiment revealed that the observed improvement was not due to the fact that the jiggling target covered larger area or stretched the target-flanker distance. We conclude that adding jiggling motion to the target can disrupt the adverse interaction between letters (crowding) and can significantly improve letter recognition in the periphery.

26.416 **Contributions of target and flanker features to crowding**

Jean-Baptiste Bernard[1](jb.bernard@berkeley.edu), Daniel R. Coates[2], Susana T. L. Chung[1,2]; [1]School of Optometry, University of California, Berkeley, [2]Vision Science Graduate Program, University of California, Berkeley

Crowding refers to the inability to recognize an object surrounded by other objects. One account of the phenomenon is the inappropriate integration of object features within an integration field. However, little is known about how features from a target and its flankers are being integrated. In this study, we derived a set of combination rules of features based on human empirical data. We measured observers' accuracy for identifying a target symbol flanked by two other symbols (4000 trials per observer), presented for 100 ms at 10° below fixation. Our symbols (a set of 10) were constructed with one or two "features" — single line segments (0.5° in length) oriented at 0°, 45°, 90° or 135°. Averaged across three observers, performance accuracy for identifying single symbols was 84%, and dropped to 50% in the presence of flankers, demonstrating a crowding effect. Analysis of the error trials revealed that (1) the probability of a given segment being present in the response increased with its frequency of occurrence in the flankers; (2) error rate increased with flanker complexity (total number of flanker features); and (3) error rate increased with the number of shared features (similarity) between the target and its flankers. A model based on the human identification performance for unflanked symbols and a weighting term to represent segment positional uncertainty (72% weight for the target and 14% weight for each of the flankers) well predicts the segment frequency and the complexity effects (chi-squared test, $p<0.001$), contrary to a model based on the positional uncertainty for the whole symbol (chi-squared test, $p>0.05$). However, to capture the similarity effect, the relative weighting between the target and the flankers must decrease with increased target-flanker similarity. These results suggest that positional uncertainty of target and flanker features could account for how features are integrated erroneously during crowding.

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26.417 **A "fuller" report on mislocation errors in visual crowding**

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Identifying a crowded object in close proximity to neighboring flankers often leads to errors. One common type of error is mislocation — incorrectly identifying a flanker as the target. Mislocation errors occur on approximately one-third of all error trials, but little is known about their properties. To better understand mislocation errors, we measured letter identification accuracy for strings of three random letters (trigrams), as a function of letter contrast. In separate blocks of trials, observers reported all three letters (full report), or only one of the three letters (partial report). Responses were scored according to two criteria: (1) the reported letter matching the stimulus letter presented at a given letter position; (2) the reported letter matching any of the three letters presented, regardless of letter position. The difference in performance between these two scoring criteria represents the rate of mislocation errors. Five strabismic amblyopes were tested with their amblyopic eyes, and four normally-sighted observers were tested monocularly at 10° in their lower and nasal visual fields. Results from amblyopic observers and the normal periphery were qualitatively similar. Mislocation error rates were higher for partial report than for full report, and were highest for reporting the middle letter of trigrams. Averaged across all observers and contrast levels, mislocation error rates for the left, middle and right letter position of trigrams were 4.6±3.5%[SD], 9.6±4.8%, 6.6±4.4%, respectively, for full-report responses; and 7.3±4.3%, 18.3±13.6%, 7.3±5.1% for partial-report responses. There was a weak effect of contrast such that mislocation error rates were higher for lower-contrast letters, regardless of letter position. Among all mislocation error trials, only ~8% of the trials were due to switching of two adjacent letters. Our results suggest that while mislocation errors contribute to crowding, they are not the full story. Our findings also provide constraints on current models of visual crowding.

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26.418 **When masking is like crowding**

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Visual masking refers to impaired performance on a target stimulus when a mask stimulus is briefly presented before, during, or after the target, at the same, or at flanking locations. Crowding refers to an impaired ability to recognize objects in clutter. Although crowding and masking share very similar features, the underlying mechanisms are not yet understood. We predict that masking and crowding are both affected by the perceptive field (PF) size and are the highest inside the PF and decrease with increasing distance from the PF. To test this prediction, we used our recently developed method for estimating the size of the PF method (Lev & Polat, 2011) and determined whether crowding and masking induced similar effects; subjects with a large suppressive range will have stronger crowding and masking effects. We tested subjects under crowding and masking conditions at both the fovea and periphery. For crowding conditions we used two tasks: letter crowding and alignment task (Gabor patches); flanking masks served as the crowding elements (Bonneh, Sagi & Polat, 2007). For the masking condition we used lateral masking (spatial masking) and lateral masking followed by temporal masks. We estimated the size of the PF for each subject. We found that crowding was correlated with the masking conditions. Although there is variability among subjects regarding the masking and crowding effects, the variability is correlated within subjects; subjects that exhibit stronger masking exhibit a corresponding stronger crowding effect. The spatial range of the crowding and the masking effects was related to the size of the PF for each subject. Thus, the results suggest that masking and crowding share common mechanisms and both depend on the size of the PF. Hence, a unified low-level model of masking may explain the spatial and temporal masking effect as well as the crowding effect.

26.419 **When the picture is complete, crowding disappears, and grouping rules**

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In crowding, the perception of a target strongly deteriorates when flanked by neighboring elements. Crowding is often explained in terms of pooling, i.e., averaging target and flanker signals. The pooling hypothesis predicts stronger crowding when the number of flankers increases- in stark contrast to recent findings. Crowding of a vernier decreased when the number of flankers, longer than the vernier, increased. However, crowding remained virtually unchanged when the number of equal-length flankers increased. We proposed that crowding reduces when more long flankers are presented because this increases ungrouping of the vernier from the flankers, whereas grouping of same-length flankers is invariant with the number of flankers. Here, we show that the vernier ungroups from equal-length flank-

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ers when we "complete the flanker array". A vernier was presented at 4 deg eccentricity. The vernier was offset to the left or right. Observers indicated this offset direction. As with previous results, Vernier discrimination thresholds raised by a factor of about 15 when a single vernier was flanked by arrays of eight same-length flankers on each side. We then presented an additional same-length flanker superimposed at the position of the target vernier. Surprisingly, crowding did not increase but was halved. We propose that adding the flanker "completed" the two separate arrays of flankers into one coherent grating of flankers. In this constellation, the vernier ungroups from the "full" grating even though the vernier and additional flanker are at the same position (except for the vernier offset). We found similar effects for peripherally presented Gabors and letters.

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26.420 **Visual Crowding in Area V4 Neurons is a Stimulus Integration Effect**

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The effect of visual crowding within a cortical area V4 neuron's receptive field (RF) was studied in monkeys trained to discriminate letter-like symbols. The primary task required a fixation of a small dot until it was replaced by a 0.25 deg letter. A discriminative push of a R/L button was required. During fixation stimuli were presented within peripheral (1-8 deg ecc) RFs. The response to a stimulus placed in the center of the RF was examined as a function of the distance to one or two additional stimuli simultaneously presented at flanking positions. Single neurons were recorded with standard electrophysiological techniques. A change in response occurred only when the additional stimuli were within the RF. As the separation between stimuli narrowed within the RF one of three scenarios occurred: the response 1) increased or 2) decreased as the separation decreased, or 3) a decrease in response was rapidly reversed as the stimuli began to merge. The first scenario correlated well with the neuron's size tuning. Neurons that responded better to larger stimuli, generally summated additional stimuli added to the RF. Neurons that decreased response in presence of flanking stimuli, were usually tuned to stimulus sizes smaller than half the RF size. Rapid reversals of response as stimulus positions merged are consistent with the emergence of a new preferred stimulus. For some neurons the monkeys were required to make a discrimination of targets appearing at the RF center along with the flanking stimuli. Typical visual crowding psychophysical performance was obtained. Attending to the RF stimuli resulted in a general increase in neural activation (relative to an attend-away condition) but did not markedly affect the crowding effect. The change in responsiveness for V4 neurons under visual crowding conditions is best explained as a stimulus integration that produces a less (or more) optimal stimulus configuration.

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26.421 **Crowding in individuals with age-related macular degeneration**

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People with age related macular degeneration (AMD) who lose their central visual field must rely on peripheral vision for their daily activities, which is often difficult. One reason for this difficulty is the crowding effect, which impairs object recognition in a cluttered environment and is prominent in normal peripheral vision. However, there is little published data about crowding in AMD patients. The present study examines how crowding affects object identification in 3 AMD patients with varying degrees of visual deficits, and compares their performance to that for 6 elderly controls and 3 younger subjects. We measured contrast thresholds for an object identification task over a range of target and tangential flanker separations using QUEST. Targets and flankers were photographs of objects, and were presented above the size acuity estimated for each subject at the eccentricity tested. AMD patients viewed the stimulus with their preferred retinal locus (PRL) with unlimited viewing time. Control subjects were tested with a similar procedure at an eccentricity matching one of the three patients (two elderly controls and one young subject per patient). Target eccentricity was maintained during unlimited viewing using an eye tracker to present the stimulus only when subjects were accurately fixating. We found no clear difference in contrast threshold elevation as a function of target-flanker spacing between the AMD patients, elderly controls, and younger subjects. Although the younger subjects' contrast thresholds tended to be lower overall, the magnitude of crowding in terms of threshold elevation and its spatial extent were remarkably similar between all groups. The present findings suggest that crowding does not diminish or worsen with age. Further, patients who have developed a PRL remain affected by crowding, showing little evidence of 'uncrowding' due to learning, at least for the limited case of tangential flankers.

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26.422 **Lighting Interpretation Within Scenes Affects Crowding**

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Crowding is an inability to accurately perceive objects surrounded by visual clutter and is arguably the most fundamental limit on conscious object recognition throughout most of the visual field. The stage of visual processing at which crowding occurs is still debated. Previous research has shown crowding strength can be altered by pop-out effects. For example, crowding is decreased when binocular disparity is used to manipulate the perceived depth of targets and flankers [Felisbert et al, 2005]. Another possible depth cue is shape from shading, which produces not only a perception of depth, but also pop-out effects that reveal an inherent lighting from above assumption [Kleffner and Ramachandran, 1992]. To determine if crowding occurs after the inference of lighting direction, we tested whether pop-out caused by lighting interpretation reduces crowding. We presented oriented Gabors superimposed on shaded disks (e.g., shaded "bumps" or "dimples" with implied lighting from above). The central target Gabor was surrounded by a circular array of Gabor flankers superimposed on disks shaded in the opposite direction of the target disk. We also tested disks shaded from the side, as opposed to the top or bottom, which do not appear to have a strong depth difference. We found that target identification is improved in scenes consistent with a lighting from above interpretation, in which the target appears to differ from the flankers in depth (e.g., a "bump" among "dimples), when compared to scenes lit from the left or the right. This result is evidence that crowding of orientation occurs at a relatively late stage of processing, after lightness interpretations are completed.

26.423 **The contributions of confusion and position swapping to crowding between letter-like symbols: Evidence and a Confusion-and-Position-Swapping model**

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Most current explanations of visual crowding are descriptive. Greenwood et al. (2009, 2010) built a feature position average (FPA) model to explain crowding with letter-like symbols. Here we used crowding errors observed with a similar experimental paradigm to compare this and an alternative model. A T target in one of four cardinal orientations 12.5° above the fixation was paired with a flanker which was one of 25 "cross-like" symbols (including four Ts). The target and flanker had four configurations (flanker on the top, bottom, left, or right side of the target). Observers reported the T target orientation. T target identification rate was 92.3% when presented alone and 68.2% when accompanied by a flanker. When the target and flanker were both Ts, 62.7% of the errors were the flanker being reported as the target. When the flanker was a No-T symbol, a T symbol that was more confusable to the flanker than to the target was often reported, accounting for 50-70% of errors across stimulus configurations. A confusion and position swapping (CPS) model was thus built in which a No-T flanker was allowed first to be misperceived as a T symbol according to an empirical confusion rate and then to swap position with the target at a to-be-determined rate, PSR, the only model parameter. Greenwood's three-parameter FPA model was also tested. The correlations between observed and model generated errors were 0.442 and 0.604 for FPA and CPS, respectively, suggesting the CPS model being able to better explain the experimental data. The best-fitting PSRs of the CPS model were 0.33, 0.21, 0.28 and 0.27 for the top, bottom, left, and right flanker configurations, respectively indicating the strongest and weakest symbol-level position swapping with outer and inner flankers, respectively, and average swapping when the target and flanker were equal distance from the fovea.

26.424 How Recurrent Dynamics Explain Crowding

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In crowding, flankers impair perception of a target. For example, Vernier offset discrimination deteriorates when the Vernier is flanked by parallel lines. Pooling models explain crowding by averaging of neural activity corresponding to the Vernier and the flankers, thus, reducing signal to noise ratio. However, recently, it was shown that flankers, longer than the Vernier, lead to less crowding than equal length flankers. Adding additional long flankers reduced crowding almost fully- in stark contrast to pooling models which predict just the opposite result. These and other findings clearly show that crowding cannot be explained by local spatial interactions, but global computations are needed. Here, we show that a Wilson-Cowan type model can explain both classical, local and recent, global aspects of crowding. The Wilson-Cowan type model employs end-stopped receptive fields with isotropic excitatory connections and anisotropic lateral inhibitory connections that are reciprocal between adjacent neurons. The key feature of the models is a spread of neural activity across similar elements which are eliminated during recurrent inhibition. For example, crowding strength decreases the more long flankers are presented because these similar, long flankers inhibit each other during time consuming processing and, thus, reduce inhibition on the dissimilar Vernier. For equal length flankers, the Vernier is "treated" similarly to a flanker and is inhibited. For this reason, and in accordance with psychophysical data, crowding does not vary with the number of equal length flankers.

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26.425 Common Spatial Characteristics of Illusory Conjunctions and Crowding

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An illusory conjunction (IC) can be defined as a perceptual error in which a subject reports a stimulus that did not appear but that combines features of the stimuli that were present. Pelli, Palomares, & Majaj (2004) noted that many IC studies use stimuli whose target-flanker proximity falls within the critical spacing for crowding. For example, Prinzmetal, Henderson, & Ivry (1995) found ICs using stimuli separated by less than 15% of the target's eccentricity. On the other hand, Cohen & Ivry (1989) found ICs with stimuli whose spacing far exceeded typical crowding values, although they used a dual task procedure with an extra memory load. To test the importance of crowding-like proximity for ICs, we replicated Prinzmetal et al (Experiment 2, no-RSVP condition) and compared ICs when stimulus spacing was or was not within typical crowding values. We found ICs with small stimulus spacing but no evidence for ICs when the spacing was increased. Our second experiment replicated Cohen & Ivry (Experiment 3) and found ICs between distant stimuli. Following their procedure, subjects identified non-target stimuli before responding about the target. Our third experiment used the same stimuli as our second experiment, but the non-target identification task was removed. Stimulus durations and contrast were also reduced such that accuracy did not differ significantly between the second and third experiments. Without a dual task procedure, the number of illusory conjunctions was significantly less than would be expected by chance, suggesting that the ICs found by Cohen & Ivry may be related to issues of memory load and response selection. We have replicated previous IC results in finding a reduction in ICs when stimulus spacing was increased. Furthermore, our results suggest that the same spacing constraints critical for crowding might play a role in illusory conjunctions.

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26.426 In the averaged crowd, children are better than adults in size discrimination

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Visuospatial integration, the ability to organize and coordinate information from local elements, is not well understood in development. In a size discrimination task, we evaluated two indices of visuospatial integration in 7-9 year old children and in adults: (1) the susceptibility to visual crowding and (2) the encoding of summary statistics of visual arrays. We briefly presented a target square with flanking squares 10 deg in the periphery. We then presented two choice squares and asked observers to identify which square matched the size of the target square. We found that children were generally less accurate in flanked (i.e. crowded) displays. However, they were more accurate than adults in choosing the target size from the average size of the target-flank array. Together, our results indicate that visual crowding and statistical averaging have different developmental profiles, further suggesting that they are processed by different mechanisms.

26.427 Chinese-reading expertise leads to holistic crowding between faces and Chinese characters

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Crowding refers to the difficulty in identifying an object when other objects are presented nearby. The phenomenon of "holistic crowding" (in which the recognition of an upright target face is more impaired by upright flanker faces than inverted ones), suggests that crowding may occur at the level of holistic face representations of upright faces rather than the low-level features in the images (Farzin, Rivera, & Whitney, 2009). Presently, we examined whether the flanker-inversion effect on crowding in face recognition can be observed with non-face flankers that are processed holistically. Visual expertise leads to increased holistic processing of non-face objects, so we opted to use expertise with Chinese characters as a means of studying the generality of holistic crowding. We hypothesized Chinese characters would induce holistic crowding of faces only in individuals with sufficient expertise. In Experiment 1, a target face was briefly presented in the fovea or the periphery. The target was either presented alone or surrounded by faces or Chinese characters that were presented upright or inverted. Non-Chinese speakers ($N = 20$) and native Chinese speakers ($N = 19$) indicated the sex of the target face. Our results demonstrated that categorization performance was worse when the target was surrounded by faces compared to Chinese characters in both groups. Also, native Chinese speakers showed a stronger crowding effect when the target was surrounded by upright compared to inverted Chinese characters ($p = .035$). However, the orientation of face flankers did not modulate the crowding effect in either group. In Experiment 2, we used the same experimental design with two-tone Mooney faces and obtained the same results. Our data suggest that visual expertise (and possibly holistic processing) affects crowding even when flankers and targets belong to separate categories; therefore, the high-level components of crowding may depend less on stimulus appearance and more on processing strategy.

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26.428 Semantic processing for crowded words: Evidence from fMRI

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We have shown previously that crowded words, despite being unidentifiable and unclassifiable, still generated robust semantic priming in a subsequent lexical decision task (Yeh, He, & Cavanagh, in press, Psychological Science). Here we further explore the brain mechanisms for such semantic activation from crowded words using event-related fMRI. Participants conducted a lexical decision task for a Chinese single-character word or non-word that was presented in isolation or with four non-word flankers surrounding it. Following a 500 ms fixation display, a target for the lexical decision task was presented at a 5-degree eccentric location on top of the fixation sign for 500 ms. Eye positions were monitored to ensure the retinal position of the isolated and crowded target. The BOLD activation was collected on a Bruker 3T magnet. In the contrast of words versus non-words, we found that the crowded and isolated conditions activated the same brain regions for processing visual words. These include the left Fusiform Gyrus (FG) for orthographic processing, the left Middle Temporal Gyrus (MTG) for semantic representation, and the left Inferior Frontal Gyrus (IFG) for controlled retrieval and selection of semantic knowledge. For crowded words, the time course analysis revealed a more short-lived activation of the two sematic processing areas, MTG and IFG, compared to the activation pattern of isolated words. These results provide neural correlates for the observed behavioral semantic priming effect from crowded words with the

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same set of word/non-word stimuli. We conclude that semantic processing indeed occurs for severely crowded words, which activate a similar semantic network as do isolated words in the brain.

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Visual memory: Capacity and resolution I

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

26.429 Load-induced transient perceptual neglect is insensitive to reference frame manipulations

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Recently, Emrich, Burianová, and Ferber (2011) reported that high visual working memory (VWM) load can induce a neglect-like disadvantage in object recognition, confined to the viewer's left hemifield. The authors suggested that inhibition of the right temporoparietal junction (TPJ) which results from high VWM load causes interference with selecting objects from the left side of space. This explanation fits well with the role of TPJ lesions in causing visual neglect. But is the nature of this transient, load-induced perceptual neglect similar to the neglect behaviour observed in patient populations? One way to address this question is to test the sensitivity of this transient neglect to manipulations of spatial reference frames. Neglect patients show deficits not only in retino-centric reference frames, but also in stimulus-centered reference frames. To determine if load-induced transient neglect is also sensitive to stimulus-centred reference frames, we used a change-detection task containing conceptual cues (e.g., 'left', 'above') to probe a memory item on each trial. Critically, subjects were told to interpret the cues within a particular reference frame (rotated 0°, 90°, or 180° from the retino-centric frame) fixed throughout an entire block. Performance on the change-detection task served as a manipulation check to monitor subjects' ability to maintain the stimulus-based reference frame. Object recognition stimuli were presented on 30% of trials, bilaterally, allowing a comparison between both the retino-centric and stimulus-centered left and right. Results suggest that load-induced transient neglect is only a function of the retino-centric reference frame and does not depend on higher-order reference frames. Importantly, these results suggest that load-induced perceptual neglect does not capture the full extent of visual neglect symptoms and is primarily due to inhibited visual encoding.

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26.430 Estimating the quantity and quality of working memory representations with continuous report versus change detection

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Recent research has made progress by estimating both the quantity and fidelity of working memory representations. For example, the precision of working memory representations decreases as more items are remembered, and the exact shape of this function has been used to distinguish between slot-models (Zhang & Luck 2008) and resource-models (Bays & Husain, 2008) of memory. Thus, it is important to validate the methods used to estimate the quality and quantity of memory representations. Here we compare estimates derived from mixture models of performance in two different behavioral paradigms: continuous report and change-detection. In the continuous report task, observers saw a set of colors, followed by a brief retention interval, and a cue to report the color of a randomly selected item. Observers could choose any color on the color wheel, and the quantity and quality of memory representations was estimated from the distribution of errors (Zhang & Luck, 2008). In the change detection task, observers saw a set of colors, and after a brief retention interval, a second display appeared in which all items were identical, or one item changed color by some amount on the color wheel (e.g., 5, 10, …180 degrees). By modifying a signal detection model (Wilken & Ma, 2004) to include a guessing parameter, we again estimated the quantity and quality of memory representations. The estimates from the two tasks were in high agreement for set size 1 and 3, but diverged at higher set sizes where the change detection task yielded higher estimates of the number of items remembered, and lower estimates of memory precision. These findings raise the possibility that the continuous report task underestimates the number of items stored and the decrease in memory precision as set size increases, which would have important implications for theories of working memory capacity.

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26.431 Oscillatory mechanism underlying the VSTM capacity limit: In mind, out of phase

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Visual short term memory (VSTM) enables us to hold a limited amount of information online. ERP studies have discovered a neural correlate of VSTM capacity called the contralateral delay activity (CDA) that tracks how many objects are maintained in VSTM when presented in a single visual hemifield. However, the oscillatory activity that underlies this averaged signal is not well understood. To examine the neural mechanisms, we analyzed the time frequency signals from scalp EEG while participants were performing a whole field change detection task. Specifically, participants were presented with either 1,2,3,4,6, or 8 colored squares for 150ms across the whole visual field, and they were asked to remember as many of them as possible across a 1300ms long retention interval. Here we found that power in the alpha frequency band (8~14hz) during the VSTM retention interval showed a linear reduction from 1 to 3 items, reaching a plateau for larger array sizes. Furthermore, the amount of alpha power reduction in the supra-capacity set sizes (i.e. 4,6 and 8 items) relative to the sub-capacity set sizes (1 and 2 items) highly correlated with individuals' VSTM capacity estimates such that high capacity individuals successfully reduced the alpha power even in the supra-capacity set sizes whereas low capacity individuals could not. This pattern of power reduction is in line with the phase-shifting account of VSTM capacity (e.g. Siegel, Warden, & Miller, 2009, Raffone & Wolters, 2001) in which object representations in VSTM are individually coded with a carrier frequency (e.g. alpha) separated in phase.

26.432 An Emergent Hemifield Asymmetry for Visual Short-Term Memory Capacity

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Severe Hemispatial Neglect is predominantly observed with right hemisphere (RH) parieto-temporal lobe damage and rarely observed with left hemisphere (LH) damage. The Representational Model of Neglect (Heilman and Van Den Abell, 1980) accounts for this asymmetry by suggesting that RH codes space bilaterally, while LH codes only contralateral space; however visual mapping of the parietal lobe fails to support this model (e.g., Swisher et al., 2007). Recently, our lab (Sheremata et al., 2010) observed that a hemispheric asymmetry emerged within visuotopically mapped parietal regions as visual short-term memory (VSTM) load increased; visuotopic RH parietal structures coded bilateral VSTM targets, while LH parietal structures coded contralateral targets. Curiously, no behavioral differences were observed with unilateral target presentation. To account for these findings, we propose a Dynamic Representational Model: 1. RH capacity > LH capacity; 2. hemispheres normally code contralateral space; 3. RH, but not LH, shifts resources to the ipsilateral field if contralateral load is low. The switching property of this model accounts for equal hemifield performance with unilateral targets, and makes the novel prediction that if targets are spread bilaterally, VSTM capacity in the LVF should exceed capacity in RVF, because the RH would be less able to aid the LH in RVF. We tested this prediction in behavioral change-detection VSTM experiments (N=40), using bilateral and unilateral target conditions. With unilateral presentation, LVF and RVF performance was equal; however, with bilateral presentation, capacity was significantly lower in the RVF ($p < 0.05$). These findings confirm model predictions. A second experiment (N=40) investigated influences of bilateral distractors and failed to observe an asymmetry ($p > .5$). We conclude that the presence of LVF targets, but not distractors, occupies the RH, limiting its ability to aid the LH in coding RVF targets. These experiments support the view that RH spatial coding changes dynamically with task demands.

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26.433 Visual working metamemory

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Saturday PM

Metamemory is the cognitive capacity to make decisions about the existence and fidelity of one's own memories. Here, we describe two experiments that demonstrate high-quality visual working metamemory. Participants were asked to remember the colors of a set of colorful dots. In the first experiment, on half of the trials participants reported the color of the item they remembered best, while on the other half of the trials they reported the color of a randomly-selected item (these two conditions were interleaved and revealed only after removal of the stimulus). We found that observers showed considerably less error for the best-remembered item than for one selected at random (SD of error distribution: 21° vs. 15°, $p < 0.005$). Using extreme order statistics, we show that this improvement implies that metamemory is of high quality. In a second experiment, participants gave a confidence rating on each trial in the form of an arc drawn over the color wheel, centered on the reported color, which represented the smallest range that the participant was fairly certain would contain the true color. We found that when participants drew larger arcs, their memories were less precise and they were more likely to guess blindly. The relationship between drawn arc size and imprecision (i.e., the standard deviation of the error distribution) was well fit by a linear function; similarly, the relationship between drawn arc size and guess rate was well fit by a logistic function. Together, the results of these experiments reveal high-quality visual working metamemory: participants can make decisions about the existence and fidelity of their working memories.

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Saturday PM

26.434 **Retro-cue improves visual working memory performance without changing the number of items being maintained**

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Visual working memory (VWM) capacity is known to be severely limited, and most individuals can accurately maintain about three items simultaneously. However, it is known that individuals can boost their VWM performance by utilizing a cue presented well after the offset of the memory array (retro-cue effect). The fact that this effect outlives the typical iconic memory duration (~1sec) has led some researchers to propose that VWM can hold more information than typically thought. To better understand the role of VWM in the retro-cue effect, we recorded ERPs while subjects performed a VWM recall task in which a cue was often presented during the retention period. First, by manipulating the type of the cue stimulus (i.e. dot position cue and color patch cue) and its SOA from the memory array, we found that the retro-cue effect is best observed with a dot position cue presented at the shortest SOA, and is the smallest with a color patch cue across all SOAs. This suggests that the representation subserving the retro-cue effect decays over time, and is vulnerable to the masking effect induced by the cue stimulus. Such characteristic is in stark contrast with VWM representations that do not decay, and are resistant against masking. To further demonstrate the contrast, we examined the neural activity during the retention interval using ERP techniques. Here we found that the magnitude of the retro-cue effect was strongly predicted by the amplitude of P3 wave induced by the onset of the retro-cue. Critically, the amplitude of P3 wave and the behavioral retro-cue effect was independent of individuals' VWM capacity and its neural correlate (Contralateral delay activity). Taken together, the retro-cue effect is obtained by accessing a residual representation that is held outside of VWM, and therefore that is vulnerable to masking and decays over time.

26.435 **Dopamine modulates visual working memory precision**

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The role of dopamine in visual working memory (WM) functions is not fully understood. We investigated the effects of dopaminergic drugs on precision of WM recall in Parkinson's disease (PD) and healthy people. In PD patients, we examined precision of memory on a serial order task, in which participants observed four differently coloured oriented bars presented sequentially, one at a time at screen centre. Afterwards, they were asked to adjust a coloured probe bar's orientation to match the orientation of the bar with the same colour in the sequence. We quantified precision as the reciprocal of the standard deviation of error in response orientation. The results show a deficit in WM precision in drug-naïve PD patients compared to age-matched controls. But this deficit was restored back to normal within 2-3 months of being treated with a regular daily dopamine agonist medication. Sensorimotor control tasks showed no change in performance pre- and post-medication, and compared to age-matched controls. We next investigated the effect of a single dose (1.5 mg) of cabergoline, a dopamine agonist, and placebo in healthy young participants performing the same WM task. The results showed that the effect of cabergoline on performance was dependent on participants' baseline performance. While high baseline performers were impaired with cabergoline, those with low baseline performance improved on the drug. There was a negative correlation between improvement in precision on medication and baseline performance. These findings demonstrate that dopaminergic stimulation can improve WM precision in PD patients and healthy low performing individuals. Conversely, it can impair performance in healthy high performers, consistent with the view that there might be an inverted U-shaped function relating dopaminergic dose to optimal WM precision.

Visual memory: Statistics, masking, configuration

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

26.436 **Does variability affect statistical averaging of length and orientation?**

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Limited attention capacities necessitate statistical summary representations such as statistical averaging. We examined how statistical averaging might be affected by feature type and variability in the set. Do we average length and orientation in a similar way? How similar should the items be in order to be averaged? Participants were presented shown sets of lines (n = 2, 3, 4, 9) for 133 ms. In Expts. 1-2, participants were asked to identify the length that represented the average or a member of the set. The lines were uniformly vertical in Expt. 1 and were randomly oriented (between -75 and +75 deg) in Expt. 2. In Expts. 3-4, participants were asked to identify the orientation that represented the average or a member of the set. The lines were all 2.7 deg in Expt. 3, and had randomly selected lengths (between 1.0 and 2.33 deg) in Expt. 4. Across all four experiments, we found that accuracy for identifying a set's average feature, either length or orientation, was higher than the accuracy for identifying a member feature. Adding variability to the set in a feature dimension irrelevant to the task did not affect the pattern of accuracies. These data suggest that statistical averaging is robust even in sets with heterogeneous members.

26.437 **The Reliance on Ensemble Statistics in VWM Varies According to the Quality of Item Memory**

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Brady and Alvarez (2011) found that size judgments for individual items in visual working memory (VWM) were biased toward the mean size of all stimuli in the display, suggesting that ensemble statistics interact with the representations of individual objects. We investigated how the reliance on ensemble statistics is modulated by the precision of VWM representations. On each trial, a sample display of gray circles, each with a different size, was presented, followed by noise masks. To modulate the quality of the VWM representation, the number of circles (set size) and the stimulus duration were manipulated. After the mask display, participants either 1) reported the mean size of the sample stimuli (mean judgment condition) by modulating the size of a probe circle or 2) reported the size of an individual circle presented at the location of the probe circle (individual judgment condition). To measure the influence of the mean size on memory for individual sizes, we calculated the difference between the reported individual size and the mean size of the stimuli in that display (mean-referenced performance). In the conditions where array processing was highly limited by short SOA or large set size, mean-referenced performance was reliably better than actual performance in the individual judgment condition but not different from performance in the mean judgment condition. However, the difference between mean-referenced performance and performance in the individual judgment condition decreased as SOA increased or set size decreased. Furthermore, in the individual judgment condition with the shortest SOA and the smallest set size, actual performance was reliably better than mean-referenced performance. This finding indicates that the reliance on ensemble statistics depends on the quality of the VWM representation, implying that biases may be observed only when an individual item representation is unavailable or when the quality of the individual item representation is poor.

26.438 **Statistical regularities about features are incidentally learned and used to improve change detection performance only when features are unique**

Amanda E. van Lamsweerde[1](avanla1@lsu.edu), Melissa R. Beck[1]; [1]Louisiana State University

Previous research has demonstrated that it is difficult for participants to incidentally learn and use statistical information about one feature of an object (e.g., color) to detect a change in another feature (e.g., shape; Beck et al., 2008). For example, if a red object is most likely to change shape, participants are unable to incidentally learn and use this color probability information to become better at detecting shape changes to red objects. On the other hand, participants are able to incidentally learn and use statistical information about location information to detect feature changes. For example, if a color change is most likely to occur in the far left column of a grid, participants are able to use this information to improve color change detection in that location. In the current set of experiments, we tested what conditions are required for participants to learn and use statistical information about features (color and shape) to improve change detection performance. Contrary to previous research, we found that participants are able to learn and use shape probabilities to detect color changes and color probabilities to detect shape changes, but only when all of the features of the objects on a display are unique (no repetition of shape or color in a single array; Experiment 1). However, if the objects in the array are not unique (e.g., two objects of the same shape or color may appear in a single array), participants are unable to learn and use color probabilities to detect shape changes, or vise versa (Experiment 2). This inability to incidentally learn and use statistical regularities when there is feature repetition in an array is likely not due to intertrial noise (Experiment 3) or chunking strategies (Experiment 4).

26.439 **Knock-Out: A New Form of Visual Masking**

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Previous work suggests that masks fail to produce impairment when observers attend the location of the target 200 ms or more in advance of the mask. We present here a new form of masking which persists beyond this limit. Observers were asked to detect a change in alternating displays containing an array of six line segments, one of which changed orientation by 45° on half the trials. The duration of each display was 60 ms and the inter-stimulus interval (ISI) was 420 ms. During the ISI, a square mask appeared at the location of each item for 100 ms, at a fixed stimulus onset asynchrony (SOA). Twelve observers were tested in each condition, with response times compared with those for the no-mask equivalent. A set of SOAs was tested, ranging from 60 to 320 ms. In all cases, the mask increased response times by over 1000 ms, with no significant effect on accuracy. This effect was greatest for an SOA of 220-260 ms; it remained strong even when the display contained only two elements. A variety of masks was then examined. Little difference was found between the effect of solid squares, four-dot patterns, two-dot patterns, a single dot, and a single dot that was blurred. However, masking decreased greatly for long lines extending across the display, and stimuli without local boundaries, such as a large-scale random field. Evidently, the effect required the mask to be a localized item, but was otherwise independent of its visual characteristics. The all-or-nothing character of this effect and its sensitivity to mask structure suggests that it may be due to "knock-out" – the displacement of an item from visual short-term memory (vSTM) by the localized mask. If so, knock-out may be an interesting new way to investigate the contents of vSTM.

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26.440 **The effect of masking on working memory for emotional faces.**

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There are obvious advantages to a mechanism for the efficient detection and monitoring of social threat. Indeed, angry faces elicit greater recall accuracy in working memory (WM) tasks than happy and neutral faces. However, the processes that facilitate this 'angry benefit' are not fully understood. Here we present evidence for a facilitatory process occurring early during memory maintenance. We presented study arrays of either two angry or two happy faces for 2000 ms followed 1000 ms later by a probe face. Probe faces had neutral expressions and were either the same individual as one of the faces in the study array, or (on 50% of trials) different individuals. Participants indicated by key press whether probe individuals had been present in the study array. During the memory maintenance interval (between study array offset and probe onset), scrambled face masks were presented at the same locations as the faces in the study array. Using a blocked design, the interval between study array offset and mask onset was manipulated. Intervals were: 17 ms, 117 ms, 300 ms, 500 ms and 700 ms. Masking early in the maintenance interval was done to interrupt the process of consolidation, i.e., the formation of durable, robust memory traces from the initial 'fragile' contents of memory. Later masks were predicted to disrupt consolidated WM representations. We observed the typical 'angry benefit' when masks were presented at timings of 117 ms or later. However, when the pre-mask interval was brief (17 ms), angry and happy face identities were recalled with equivalent accuracy. Interestingly, memory performance for happy faces was equivalent at all masking intervals, suggesting that early masks did not interrupt face consolidation, but instead disrupted a process that would otherwise result in angry faces developing their usual 'extra robust' memory representations.

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26.441 **The temporal dynamics of feature integration for color and form**

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When two visual stimuli are presented in rapid succession only one fused image is perceived. For example, a red disk followed by a green disk is perceived as a single yellow disk (e.g., Efron, Perc Psychophys, 1973). For two verniers that last 30ms each, it has been shown that the fusion process can be disrupted up to 420ms after stimulus onset by applying TMS over visual cortex (Scharnowski et al., J Vis, 2009). Here, we show that feature fusion can also be modulated with light masks. In Experiment 1, we used the same procedure as in the above TMS experiment: Two verniers were presented in rapid succession with opposite offset directions. Subjects had to indicate the offset direction of the fused vernier. In Experiment 2, a red and a green disk were presented in rapid succession and subjects had to indicate whether the fused disk appeared red or green. Verniers were presented for 30ms and disks for 10ms each. Light masks were presented from -100 to 240ms relative to the onset of the first stimulus. When masks were presented before the stimuli, the second stimulus dominated the percept and when masks were presented after the stimuli, the first stimulus dominated the percept. Feature fusion was modulated for a period of 240ms for both color and vernier stimuli. Our results indicate that for this duration individual memories exist for each vernier or color stimulus separately. Fusion is not completed beforehand. Taken together, our results show that light masks have similar effects on feature fusion as TMS and provide an adequate alternative to investigate feature integration. In addition, we showed that the process of unconscious feature fusion outlasts the physical duration of the stimuli by far.

26.442 **Updating visual working memory is both object-based and feature-selective**

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How do we update visual working memory? When modifying our memory of an object to integrate new information with stored information, do we use an object-based process or a feature-based process? Previous work has suggested that updating is not object-based, but rather feature-selective, because people selectively update one feature of a memorized object without refreshing the memory of other features of the object (Ko & Seiffert, 2009 Mem Cognit). To test whether updating shows any object-based ben-

Saturday PM

efit, we asked participants to update two features of their visual working memory of either one object or two objects. Participants memorized a display composed of three colored, oriented bars in three different locations. The display was followed by a cue instructing participants to update their memory of one feature of the object at the same location as the cue. To manipulate whether one or two objects were updated, a second cue either appeared at the same or different bar location as the first cue. Also, the two cues were either the same feature or different features. After the cues, a single bar probe appeared at one of the three bar locations. Participants indicated whether the probe matched their memory. The facilitation effect of updating features did not spread to the other feature of the cued object or features of other objects, for both one object (interaction $F(1,24)=21.9$, $p<.001$) and two-object (interaction $F(1,24)=7.35$, $p<.013$) updating. This was consistent with previous results showing feature-selective mechanism in updating. However, when the updated object was probed, participants performed more accurately when updating one object than two objects ($F(1,24)=29.7$, $p<.001$), showing evidence for an object-based mechanism. In addition, the feature-selective facilitation effect was significantly larger in one object updating than two-object updating ($F(1,24)=6.30$, $p<.02$). Taken together, these results suggested that updating relies on both object-based and feature-selective mechanisms.

26.443 Effects of inter-item configuration on relation working memory

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Grouping items facilitates working memory performance by reducing memory load. Recent studies reported that within-object binding of multiple features from the same dimension may facilitate encoding and maintenance of visual working memory for item-specific information, such as color or size. Further, perceptual inter-item configuration strongly influences working memory performance for item-specific spatial information. Here, we test whether forming a configuration between two items enhances short-term memory for the relationship between features of those items. To do so, we asked subjects to perform a change detection task based on the relationship between two items while the strength of the inter-item configuration was manipulated. Critically, an absolute feature value for each item varied between sample and test periods. This design ensured that subjects extracted and maintained relation information between items independent of item-specific information. We found that when items were located side-by-side, making the formation of an inter-item configuration easy, subjects' performances for remembering 1, 2, 3, and 4 relations (2, 4, 6 and 8 items present, respectively) were not different from remembering specific information for 1, 2, 3 and 4 items. When items within a pair were placed offset, thus making it more difficult to form an inter-item configuration, memory performance for relations was significantly worse than for items. Our findings suggest that encoding and maintenance of relation information are strongly influenced by perceptual factors; the presence of a strong inter-item configuration facilitates processing of relation working memory within those pairs of items.

26.444 Enhanced Familiarity with Sequential Presentations in Visual Working Memory

Andrew Yonelinas[1,2](apyonelinas@ucdavis.edu), Weiwei Zhang[1,2], Kimron Shapiro[3]; [1]Department of Psychology, University of California, [2]Center for Mind & Brain, University of California, [3]Wolfson Centre for Clinical and Cognitive Neuroscience, School of Psychology, Bangor University

Splitting the to-be-remembered items into two sequential arrays significantly increases visual working memory (VWM) relative to the simultaneous presentation of the same items (Ihssen, et al., 2010). However, the reason for this increase is unknown. The present study examined receiver operating characteristics (ROCs) to test whether the improvement in VWM is due to increased recollection or familiarity-based responses. Four colors and four shapes were presented either simultaneously (simultaneous condition), or split into two temporally separated 4-object arrays (sequential condition). Observers reported whether one of the items in the test array had the old or new color or shape, on a 6-point confidence scale, relative to the corresponding memory arrays. A larger VWM capacity was obtained for the sequential condition ($K = 3.8$) relative to the simultaneous condition ($K = 3.0$), replicating previous findings. ROCs were constructed for each condition based on the confidence data. Recollection and familiarity were then estimated from ROCs using a Maximum Likelihood Estimation procedure. The increase in the overall capacity seen in the sequential condition was due to an increase in familiarity, rather than an increase in recollection. The enhanced familiarity in the sequential condition may result from improved configural encoding that arises when two separable chunks or Gestalts are presented. These results are further discussed within the framework of biased competition.

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26.445 Features or levels? Evidence for binding levels better than features.

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When briefly presented with global and local information, individuals perceive the global information faster, a phenomenon known as the global precedence effect (Navon, 1977). In this study we investigated whether, in visual working memory (VWM), binding features to global and local levels is more likely to occur than other types of feature binding (e.g., binding features to spatial location or serial position). Ericson & Beck (VSS 2011) demonstrated that there is a bias towards global information in VWM, and that biasing attention to either global or local levels affects representations in memory. The current study expanded on this work. Across two experiments, participants performed a change detection task for three Navon figures, in which a larger (global) letter is composed of smaller (local) letters. Experiment 1 used a paradigm similar to traditional binding tasks, such that three Navon figures were displayed on the screen simultaneously. A greater proportion of errors were found when features were exchanged between two Navon figures than when the local and global features were switched within a single Navon. This result suggests that there is a bias towards level binding in VWM, and not towards binding the object features together. Experiment 2 expanded on these findings, but used a serial presentation of Navon figures for the change detection task. Overall performance replicated the result of Experiment 1, and regardless of the serial position of the Navon, a bias occured toward binding level information rather than binding object features together. Our findings give new insight to not only how the global precedence effect occurs in VWM, but also into possible limitations associated with feature-binding in VWM.

26.446 Investigating the role of spatial location in surface-feature binding: The retrieval of features and objects as a function of spatial proximity

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Recent working memory (WM) investigations have explored the role of spatial location in surface-feature binding (e.g., between colour & shape), drawing parallels with the perception literature (Treisman & Gelade, 1980). These studies suggest surface-features are bound with obligatory reference to spatial location, at least in the early phases of memory (Treisman & Zhang, 2006). Our study capitalized on this observation and examined the retrieval of surface-features (colour & shape) as a function of the spatial proximity of memorized coloured-shape 'objects'. Our single-probe change detection task presented four coloured shapes in distinct locations, with instructions to remember the colour and shape features. After a short delay, a single probe coloured shape was presented centrally. Participants judged whether this probe item represented both a colour and shape they had seen in the memory display, regardless of their initial pairing. To assess the influence of spatial proximity on feature retrieval, three probe conditions were compared: Intact probes required retrieval of colour and shape features originally associated with the same array 'object' (i.e., zero spatial distance between memorized features). Recombined-near probes consisted of a pairing of colour and shape features originally located on distinct but spatially proximal objects in the memory display. Finally, recombined-far probes comprised colour and shape features originally located on distinct and spatially distant objects in the memory display. We observed superior performance in retrieving features belonging to the same object (a 'binding effect)'; and a response latency cost in retrieving features from spatially distant relative to spatially proximal objects (a 'distance effect'). Our findings strengthen the claim that surface-feature bindings are processed with refer-

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ence to spatial location and are discussed in terms of a focus of attention in WM that retrieves stored memoranda back into conscious awareness for further processing (Oberauer, 2002).

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Attention: Capture I

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

26.447 Attentional capture correlates with inter-individual distractibility in everyday life: an electrophysiological investigation

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During a visual search task, attentional capture is the inability to inhibit the allocation of attention towards highly salient distractors. In studies using the N2pc as marker of attentional selection, only few experiments have demonstrated pure buttom-up attentional capture by salient distractors. In contrast, a larger number of experiments reported modulations of attentional capture by top-down processes. However, an important aspect of human cognition, the interindividual differences between participants, is often overlooked. The GABA level in the frontal eyed fields and the density of parietel cortex have been shown to correlate with the magnitude of attentional distraction. Because the parietal cortex is the likely neural source of the N2pc, we explored the correlation between the amplitude of the N2pc in the additional singleton paradigm and individual scores at the Cognitive Failure Questionnaire (CFQ) which has been reported to positively correlate with the density of the left superior parietal lobe. We obtained a significant correlation between the N2pc capture effect and CFQ scores. Surprisingly, participants with high distractibility had a more positive N2pc to the distractor in the attentional capture condition. During the N2pc time window, the source estimation underscores a significant difference of source current density in superior parietal lobes compared to passive viewing of the same stimuli. We will discuss the hypothesis proposed by past authors (the maturation hypothesis and compensation hypothesis) in light of the attentional mecanisms related to N2pc. Further, we investigated the specific microstate topography associated with the attentional network.

26.448 Working memory load and attentional capture by unpredicted color changes

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Previous studies have shown that new objects are more salient in capturing attention than abrupt changes in old objects, such as color changes. One exception is a study by Lu and Zhou (2005, Psychonomic Bulletin & Review), which reported strong capture for color changes. However, we had argued that capture only occurred because the search item colors were randomly switched between trials (von Muhlenen and Conci, 2009, Psychological Research). The current study investigates how attentional capture depends on the interaction between type of task (detection, discrimination) and experimental design (blocked, mixed). The first two experiments used a target detection task (i.e., search for a letter "U", absent or present), whereas the third and fourth experiments used a target discrimination task (i.e., search for a letter U or H). In both task types the actual displays and the used response keys were the same – the only difference was the instruction. Experiment 1 used the detection task in a blocked design (fixed color assignments); the result showed that under these conditions a color change did not capture attention, replicating previous studies (e.g., von Muhlenen & Conci, 2009). Experiment 2 used the detection task in a mixed design (random color assignments); now a color change did capture attention, replicating Lu and Zhou (2005). Experiment 3 used the discrimination task in a blocked design and found again no capture effect, also in line with previous studies (e.g., von Muhlenen, Rempel & Enns, 2005, Psychological Science). Finally, Experiment 4 used the discrimination task in a mixed design and found no capture effect. These findings can be explained within the framework of an attentional guidance model where the ability to ignore an event depends critically on the continuity of the color assignments and on the amount of working memory required by the specific type of task.

26.449 Non-salient pop-out attracts attention and the eyes

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We used local violations of regularities within visual images and with a low calculated salience to test whether pop-out is different from salience. In line with this, lowly salient violations of the overall image pattern attracted the eyes and attention. We used patterns consisting of tiles, either forming a fully regular pattern, or a locally irregular pattern. Within a visual search task, in half of the trials one of the tiles stood out because it was rotated so as to violate the overall regularity (here: of point symmetry at 16 locations). Although this pop-out tile was anti-predictive for the target location (i.e. never at the target position), we found that participants significantly more often fixated on this image position than on every other location, and the mere presence of the rule violation (i.e. the rotated tile) slowed down correct target detection. In Experiment 1 (N=38), we also varied the local feature salience of each tile relative to its surround, and found this was without additional effect on attraction of the eyes and attention by the rule violation. We also found a facilitation effect when the target was located at the same position as the rule violation (Exp. 2, N= 16), and results could be replicated with photographs of natural scenes (Exp.3, N = 16). Our results point to rule violations as one major origin of attentional attraction by pop-out stimuli.

26.450 Parametric manipulation of attentional conflict in the additional-singleton paradigm

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According to the computational conflict monitoring model of Botvinick et al. (2001), cognitive control recruitment in conflict tasks should be modulated on a trial-by-trial basis. Based on this, two hypotheses concerning conflict adaptation can be derived: Conflict interference should not only be reduced in blocks with high conflict frequency compared to blocks with low conflict frequency, but should also show gradual modulations on a trial-by-trial basis if conflict probability is parametrically manipulated. In addition, conflict interference should not only be reduced on trials immediately following a conflict trial, but should also show a gradual reduction over a sequence of multiple conflict trials. We empirically tested those predictions in two visual search experiments, in which the presence of a salient but irrelevant distractor may generate a conflict as to where focal attention should be allocated. Unlike common practice, we analyzed non-aggregated RT data by mixed model (multilevel) regression, which allows for trial-by-trial predictions to be tested on a trial-by-trial level. In Experiment 1 distractor probability (for a given trial) was parametrically manipulated: It varied sinusoidally from low to high and back to low over the course of the experiment. Distractor interference developed inversely proportional to conflict probability, i.e. distractor interference decreased with increasing distractor probability and increased again with decreasing distractor probability. In Experiment 2 the number of consecutive conflict encounters (i.e., distractor-present trials) was parametrically manipulated: Twenty sequences of ten consecutive distractor-present trials were presented over the course of the experiment. Distractor interference during those sequences showed a linear decrease with an increasing number of conflict encounters. Overall, those results are in line with the predicted trial-by-trial adjustments we derived from the conflict monitoring model of Botvinick and colleagues. Additionally, they further support the notion that conflict adaptation effects observed for response conflict can be generalized to attentional conflict.

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26.451 The capture of attention by abruptly onsetting new objects under conditions of unexpectedness and unpreparedness

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The control of attention has to accomplish two aims. First, attention has to be directed to vital events of the environment that are relevant to survival, independently of the current goals. Second, attention has to be maintained in accord with the current task demands. These two types of attention are often referred to as involuntary and voluntary attention. A particular variant of involuntary attention is attentional capture, where attention is involuntarily relocated away from its current focus. One of the proposed conditions for attentional capture has been the presentation of an abruptly onsetting new object. Evidence comes from experiments where task irrelevant onsets that were not predictive of the target's position nonetheless biased attention to their position. Concerns, however, have been raised whether these effects are actually independent from the current task and intentions. The current experiments explore the conditions of onset capture when strategies related to the onset can be excluded with certainty, that is, on the unannounced first presentation. Participants worked on an inefficient visual search task for a while, when in the critical trial, an onset cue was presented either near the target (valid condition) or at distance from the target (invalid condition) without prior warning or information. In the critical trial, large validity effects were observed, which were also found to be stronger than in the post-critical trials, where the non-predictive onsets were repeatedly presented. Further conditions suggest that capture was not due to a general task driven set to detect onsets, and that presenting a new shape (without an onset) does not capture attention. It is concluded that abruptly onsetting new objects pass the test for attentional capture, even when strategies can be excluded by testing their unannounced first presentation.

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26.452 **The transfer of abstract attentional sets across different types of visual search**

Tashina Graves[1](tgrave15@jhu.edu), Howard Egeth[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

If people have been performing a visual search that forces them to use either a diffuse or focused attentional set, will they keep using a similar attentional set even when they switch to a different search task? The transfer of attentional sets, or search strategies, has already been demonstrated within several task paradigms. Participants who were forced to use either a singleton detection strategy or a feature search strategy on training trials continued to use the same strategy on later test trials where either strategy was a viable option. Long-lasting transfer effects can occur even when the training trials and test trials use a different color set. The current study examines whether the abstract transfer of attentional sets can happen when entirely different tasks are used for training and test. Participants were trained with either the singleton or feature version of the additional singleton task, which involved a spatial shape search, and tested with RSVP contingent capture option trials, which involved a temporal color search. Different color sets were used for the training and test tasks. We found no evidence of attentional set transfer. Instead, both sets of participants opted to use a feature search strategy. A control experiment confirmed that feature search was the default strategy for RSVP option trials, which was surprising given previous findings of singleton detection mode use for RSVP option trials. The lack of transfer, coupled with previous findings of no correlation between the amount of capture by a distracting stimulus on the additional singleton task and on the RSVP contingent capture task, might indicate a fundamental difference in the attentional mechanisms recruited for each task.

26.453 **Action video game players resist oculomotor capture, but only when told to do so**

Joseph Chisholm[1](jchisholm@psych.ubc.ca), Alan Kingstone[1]; [1]University of British Columbia

A sizable body of work has accumulated over the past decade highlighting the relationship between action video game experience and benefits in cognitive task performance. Research has been largely consistent in demonstrating that action video game players (AVGPs) outperform non-video game players (NVGPs) especially in tasks that involve selective attention. We, along with others, have previously demonstrated that AVGPs are better able to resist the interfering influence of task-irrelevant distractors and have argued for a top-down mechanism to account for these attentional effects. However, it is unclear whether AVGPs will always demonstrate reduced interference from distraction or whether this effect only occurs when they are explicitly instructed to avoid distraction. To address this question, we ran two experiments, collecting eye movements and manual responses from AVGP and NVGP in a traditional oculomotor capture paradigm. Participants searched for a colour-singleton target, while a task-irrelevant abrupt onset appeared on 50% of trials. In Experiment 1, where participants were not informed of the appearance of the abrupt onset, AVGPs failed to demonstrate reduced capture relative to NVGPs. In Experiment 2, participants were informed that an abrupt onset would appear but that it was task-irrelevant and to be ignored. Results indicate that when told to ignore a task-irrelevent distractor, AVGPs demonstrate reduced capture by an abrupt onset relative to NVGPs. These findings not only provide further evidence that the attentional differences observed between AVGPs and NVGPs on tasks of selective attention are subserved by a difference in top-down control but that it is also specific to given task demands. In addition, these findings lend further support for the notion that the capture of attention is susceptible to top-down influence.

Acknowledgement: NSERC

26.454 **Missed rewards capture attention**

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Emerging lines of evidence demonstrate the importance of rewards and penalties in guiding attention. Previous debate on the capture of attention by salient visual stimuli has centred on whether distraction is modulated by goals. But capture is ecologically advantageous precisely if the risk of ignoring a new event outweighs the expected utility of the current goal. Such a perspective predicts that rewards and penalties might modulate distraction. In this study we used a variant of an oculomotor capture paradigm (Theeuwes et al., 1998) to index bottom-up attentional allocation. In such tasks, participants must look towards a non-salient target item, but gaze is often involuntarily captured by a neighbouring bright distractor. We rewarded subjects for each saccade to the correct target, according to their reaction time, while saccades to the salient distractor incurred a fixed penalty. First, we explicitly manipulated the magnitude of reward and penalty across blocks. Oculomotor capture was significantly reduced by expectation of value. Penalties did this at the expense of slowing down responses, whereas modest rewards simultaneously hastened responses and reduced capture. Next, we examined the effects of reward history by systematically manipulating the location of the valued and penalised items on the previous trial. The key new finding was that oculomotor capture was specifically exaggerated when a reward was previously missed at the current distractor location. This could not be explained simply on the basis of speeded reaction times, inhibition of return, or motor perseveration. Our findings argue that attentional capture is reward sensitive, and that recently-missed rewards exert a dynamic, spatially specific pull on the guidance of bottom-up spatial attention.

Acknowledgement: Funded by The Wellcome Trust

26.455 **The role of reward in driving attention shifts.**

James Retell[1](j.retell@uq.edu.au), Ashleigh Kunde[1], Mei-Ching Lein[2], Roger Remington[1]; [1]The University of Queensland, [2]Oregon State University

Attending to visual stimuli associated with a high probability of procuring rewards is greatly adaptive. Exactly how reward interacts to guide visual attention is presently unclear. Recent research suggests high-value, but contextually irrelevant stimuli, capture attention as a consequence of reward learning and that this capture occurs independently of task goals and visual salience. Here we investigated whether stimulus reward associations learned in a visual search task, would influence performance in a subsequent spatial cueing task. The aim was to test whether reward learning would attached to specific features (feature hypothesis), or whether stimulus reward associations are specific to the context in which they are learned (context hypothesis). We further explored the conditions in which stimulus-value associations are formed by examining whether value learning requires rewarded features to be the explicit goal of search (explicit-reward hypothesis), or if value attaches to all features of an attended object (implicit-reward hypothesis). Consistent with previous reports of value-driven capture, we found significant cueing effects for high-reward stimuli (feature-hypothesis). Furthermore, significant cueing effects for high-reward stimuli were observed when the rewarded stimuli did not define the search target during the learning phase (implicit-reward hypothesis). Here we extend on previous finding by demonstrating that reward attaches to the feature defined in training, rather than the context and that these stimulus reward associations may be learned implicitly.

26.456 **Value-driven Attentional Capture by Rewarded Orientations**

Patryk Laurent[1](laurent@jhu.edu), Brian Anderson[1], Michelle Hall[1], Steven Yantis[1]; [1]Department of Psychological and Brain Sciences, The Johns Hopkins University

It is well-established that visual attention is guided by the physical salience of stimuli and by their congruence with ongoing goals. More recently we have also shown that attention can be captured by stimuli that are neither salient nor goal-related, but that possess a feature (namely, a particular color) that has been previously associated with reward. Participants are slowed in visual search and Eriksen flankers tasks when previously rewarded distractors are present, and this effect increases with the value of the distractor. It is unknown, however, whether value-driven attentional capture can occur for reward-associated features other than color. The aim of the current study was to determine whether another feature, orientation, could be imbued with reward value and thereby cause value-driven attentional capture. Participants underwent a training phase (576 trials on day 1 and 240 trials on day 2) during which they searched for a near-vertically or near-horizontally oriented Gabor patch within arrays of six Gabor patches, and reported the color of the target patch. On correct trials, participants were stochastically rewarded with 5 cents or 1 cent depending on the orientation of the vertical or horizontal patch (high probability of high reward for near-vertical and high probability of low reward for near-horizontal or vice-versa, counterbalanced across participants). In a subsequent unrewarded test phase (480 trials on day 2), participants were instructed to search for the spatial-frequency singleton Gabor patch and to report its color. During half of these trials a near-vertically or near-horizontally oriented Gabor patch (confirmed to be nonsalient in a control experiment) was presented as a distractor among diagonally-oriented patches. Response times on these trials were significantly slowed when a previously rewarded orientation was present. The results show that attention is captured by formerly rewarded orientations and extend the generality of value-driven attentional capture.

26.457 **Value-Driven Oculomotor Capture**

Brian Anderson[1](bander33@jhu.edu), Steven Yantis[1]; [1]Psychological & Brain Sciences, Johns Hopkins University

Covert shifts of attention precede and direct overt eye movements to stimuli that are task-relevant or physically salient. We have recently shown that stimuli imbued with value via reward learning also capture attention involuntarily, even when they are not salient and irrelevant to the current task (Anderson, Laurent, & Yantis, 2011, PNAS). Although it is known that both salient and goal-related stimuli draw involuntary movements of the eyes, an effect termed oculomotor capture, it is unclear whether valuable stimuli can similarly capture the eyes. We assessed the effect of previously reward-predictive but currently irrelevant distractors on visual search for a salient target using eye tracking. The experiment consisted of a training phase in which participants were rewarded for identifying colored targets, and an unrewarded test phase in which nontarget items were occasionally rendered in the color of formerly reward-predictive targets (these constituted valuable distractors). Our results show that valuable stimuli both slow responses to the target and are significantly more likely than other nontargets to draw eye movements; they do so persistently throughout the test phase. By measuring dilations of the pupil evoked by target stimuli throughout the course of training, we also show that reward-predictive targets gradually come to evoke anticipatory arousal; this provides physiological evidence that the stimuli that elicit value-driven capture come to serve as reward-predictive cues. Our findings demonstrate that when a stimulus is learned to predict reward, that stimulus acquires incentive salience which in turn drives both attentional and oculomotor selection in a manner that persists into extinction. This normal cognitive process is similar to biases in stimulus selection found in drug addition, suggesting a potential link between value-driven capture and addiction.

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26.458 **Inhibition of distractor features in the attentional control setting**

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The contingent involuntary orienting hypothesis posits that an object captures attention only if it possesses the critical target-defining feature (Folk et al., 1992). The hypothesis is silent regarding the role that might be played by the distractor-defining feature(s). We examined, using the spatial cuing paradigm, whether the attentional control setting may be configured such that there would be top-down inhibitory control of the critical distractor feature(s). When the search array was presented, the target location was marked by a specific feature (e.g., the color red). A different feature on the same dimension defined the distractor locations (e.g., the color green). The question was whether a salient irrelevant cue (i.e., a singleton), presented before the search array was presented, would recruit attention to its location. As the cue was irrelevant, attentional deployment to its site would be considered an instance of attentional capture. The diagnostic for capture is a shorter search latency for the target if it appeared in the same location as the irrelevant cue, and a longer latency if the target appeared in a different location from the cue. But, if the irrelevant cue had been suppressed, this facilitation ought not to be observed. Our results, consistent with the contingent involuntary orienting hypothesis, showed a facilitation effect when the irrelevant cue possessed the critical target feature. But, when the irrelevant singleton shared the defining feature of the distractors, capture failed, suggesting inhibition occurred. More interesting was the case in which the irrelevant cue had neither the critical feature of the target nor the distractor color. The cue succeeded in capturing attention, a finding that is consistent with the view that a salient object would succeed in capturing attention so long as the object's features were not suppressed via top-down inhibitory control.

Attention: Neural mechanisms and models I

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

26.501 **Flat BOLD-o-metric functions in motion direction discrimination in human visual cortex**

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It is commonly assumed that BOLD responses in the visual cortex are modulated by task difficulty. Here we directly tested this assumption using two fMRI experimental designs: event-related and blocked. In each trial, a static fixation cross † was first presented for 600 ms, with its longer arm serving as the directional reference that is randomly selected between 0° and 360°. Then a random-dot kinematogram (coherence: 100%, number of dots: 400, speed: 10°/sec, stimulus diameter: 8°) was presented for 200 ms. Subjects indicated whether this motion direction was clockwise or counter-clockwise with respect to the reference. The directional difference was either 3° or 9° or 15°. In the rapid event-related design, the order of trials was randomized and counterbalanced with M-sequences. In the blocked design, stimulus blocks (18 sec) were interleaved with blank blocks (12 sec). Each stimulus block consisted of six trials, all of which shared the same directional difference in absolute value. Fourteen subjects participated in this within-subjects study, with counterbalance. Behaviorally, the three directional differences gave rise to, as expected, different accuracies: 62%, 78%, and 88%. BOLD signals were analyzed in V1, V2, V3, V5/MT+, and intra-parietal sulci (posterior and anterior), all of which were sensitive to visual motion. No modulation of BOLD was found in any of these areas. We conclude that BOLD signals in the human visual cortex are not a function of task difficulty or behavioral response accuracy.

26.502 **Overlapping neural circuits for visuospatial attention and eye movements in human cerebellum.**

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Previous research in patients with cerebellar damage suggests that the cerebellum may play a role in visual attention. One limitation of some of these studies is that they examined patients with heterogeneous cerebellar damage. As a result, the patterns of reported deficits have been inconsistent. In the current study we used functional neuroimaging (fMRI) in healthy adults (n=14) to examine whether the cerebellum plays an important role in visual attention. During the fMRI session, subjects performed two covert attention tasks in which they were cued (with peripheral flashes or central directional arrows) to attend to marked locations in the visual periphery without moving their eyes. Using a block design, we compared BOLD activation in these covert attention conditions to a number of control conditions

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including: the same attention tasks with eye movements, a target detection task with no cuing, and a self paced button-press task in order to rule out the possibility that any activation observed in the cerebellum during the covert attention tasks might be due to motor output associated with task performance. Results indicated that, in addition to the usual fronto-parietal networks commonly engaged by this visual attention task, two regions of the cerebellum (lobule 6 in the left posterior quadrangular lobe and the culmen) were active when subjects performed the attention task with peripheral cues with or without concomitant eye movements. The same regions of the cerebellum were not active, however, when subjects performed the covert attention task using central arrow cues. This suggests that the cerebellum may play a critical role in both shifting attention and generating eye movements towards stimuli that suddenly appear in the periphery. These results are consistent with the pre-motor theory of attention which posits that shifts of attention are generated through the programming of eye movements that are not executed.

Acknowledgement: This research was supported through a Natural Sciences and Engineering Research Council (NSERC) of Canada Postdoctoral Fellowship to C.L.S, a Canadian Institutes of Health Research (CIHR) operating grant awarded to M.A.G., and a University of Western Ontario Academic Development Fund (ADF) grant awarded to S.R. The authors would like to thank Adam McLean and Kim Krueger for technical assistance with the fMRI scanning.

26.503 **The effect of competition on early visual ERP components**

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Although competition between inputs in early visual areas of the brain is known to be a key determinant in perception (e.g., biased competition, Desimone and Duncan, 1995), many investigators give little thought to this when choosing their stimulus parameters. To study this, we employed the ERP approach in fifteen participants aged 19-33 who were presented with checkerboard stimuli (100 ms duration) to elicit C1, C2 and P1 components. Participants were given the task of responding to infrequent 'targets', but the analyses focused on target-absent trials to obtain a measure of competition unaffected by response demands. Stimuli were presented in three randomised conditions: single stimulus, near proximity pairs (0.16° apart) and far proximity pairs (2° apart). Competition predicts a reduced response to a stimulus when presented as part of a pair relative to when presented alone, with greater reduction predicted for pairs that are closer together. Evidence for competition was observed in the C2 wave, likely reflecting feedback into area V1, and the P1 wave, likely reflecting extrastriate cortex. These findings suggest that competition influences sensory encoding. This method provides an empirical means of measuring competitive interactions at specific stages of visual processing, which will make it possible to rigorously test predictions about the effects of competition on perception, attention, and working memory.

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26.504 **Real-time decoding and training of attention**

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Selective attention is needed to prioritize the subset of sensory information that is most relevant to our goals. Unfortunately, selective attention is prone to lapses, even in situations where sustaining focused attention is crucial (e.g., when driving in traffic). We propose that such lapses occur partly because we lack a subjective sense of when we are or are not attending well, and that with an appropriate feedback signal, attention can be trained and enhanced. We report initial steps in the development of a closed-loop real-time fMRI system where we use multivariate pattern analysis to provide neurofeedback and train attention. During an fMRI session, observers were presented with a continuous stream of composite face/scene images; occasional shift cues were presented indicating which category should be attended and responded to. Data were pulled from the scanner and preprocessed in real-time (with motion correction, masking, smoothing, and temporal filtering). Whole-brain data obtained under each category cue were used to train a classifier to predict observers' attentional state. Despite the fact that stimuli were identical in the attend-face and attend-scene conditions, we obtained highly reliable classification performance in real-time for individual trials. This successful real-time decoding allows us to provide immediate and time-varying feedback to observers regarding how well they are attending to the cued category (e.g., tinting the screen background more green or red to indicate increasingly correct or incorrect attentional focus, respectively). By staircasing behavioral performance to a fixed level of accuracy before providing feedback (adding phase-scrambled noise), we can also examine whether neurofeedback (vs. sham or no feedback) improves accuracy in the behavioral task. In sum, by applying multivariate pattern analysis in real-time to fMRI data, we can provide observers with a sophisticated and timely readout of attentional focus that may prove useful in training attention.

26.505 **Population receptive field estimation of visuotopic areas in the human intraparietal sulcus**

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The intraparietal sulcus (IPS) is known to have multiple visuotopic areas, but functional characteristics of these areas are not well understood. In the present study, we investigated differences in functional architecture across visuotopic IPS areas by population receptive field (pRF) analysis. In early visual areas, both electrophysiological studies and neuroimaging studies revealed that receptive field size is the smallest in V1 and increases through visual processing hierarchy. We are interested in whether this kind of hierarchical relationship also exists among the IPS areas. We first compared visual filed maps of the IPS based on phase-encoded analysis and pRF analysis. Participants observed rotating wedge or expanding rings, while performing spatial attention task to the stimulus. In the phase-encoded analysis, fMRI time series were Fourier transformed and response phase were plotted on the inflated cortical surface. In the pRF analysis, pRF parameters were estimated for each voxel, and receptive field position were plotted. Visual field maps produced by both methods were in good agreement. Based on these maps, five areas (IPS0, IPS1, IPS2, IPS3, and IPS4) were identified for each participant. Next, we investigated how pRF size changes as a function of eccentricity in visuotopic IPS areas. In all of identified areas, pRF expanded as visual field eccentricity become larger, as known in early visual areas. In contrast, pRF size in parafoveal region reached at maximum in the IPS1, and no difference was observed in more anterior areas. These results indicate that visuotopic areas in the IPS do not have hierarchical structure observed in early visual areas in terms of pRF organization. In monkey electrophysiological studies, the IPS is known to be divided into multiple functionally distinct areas. Similar functionally diverse organization in the human IPS is probably reflected in pRF structure, where information is processed in parallel, rather than hierarchical.

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26.506 **Neural correlates of multiple object processing in the absence of awareness**

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When we look at a complex scene we are able to perceive a limited set of objects simultaneously. Such ability involves at least two stages of processing. Early individuation processes tag a limited number of elements by binding basic features to object locations and produce approximate representations of the indexed objects. Subsequent mechanisms, likely dependent on Visual Working Memory (VWM), encode in greater details the individuated objects, ultimately leading to their complete representation. Using a four-dot masking procedure the present electrophysiological study investigated whether the functioning of early and late stages of multiple object processing requires awareness. We measured N2pc, a neural marker of individuation, and CDA, a marker of VWM, while participants saw a variable number (from 0 to 3) of uniquely colored target-dots displayed among distractors. Participants' task was to report target numerosity. On target-present trials, one target and one distractor were surrounded by four dots. The four-dot mask could offset together with the stimuli (common-offset) or not (delayed-offset). Results showed that participants were less accurate in delayed-offset trials than in common-offset trials, indicating that

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targets were successfully masked. ERP results showed that the amplitudes of both N2pc and CDA decreased in delayed offset trials. However, while the N2pc amplitude increased as function of numerosity in both delayed and common-offset trials, such modulation in the CDA was found only for the common-offset condition. Further analyses on the N2pc for the delayed-offset condition showed a numerosity-related modulation in both correct and incorrect trials. These results indicate that although awareness overall affects the functioning of multiple object analysis, multiple target individuation can operate in conditions of reduced awareness. In contrast, detailed encoding procedures on multiple targets are significantly less effective with reduced awareness. This in turn suggests that awareness is progressively required to build a full representation of multiple objects.

26.507 **The role of attention in repetition attenuation and pattern similarity during visual learning**

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We investigated the role of attention in two measures of stimulus-specific learning: repetition attenuation, and pattern similarity. Repetition attenuation refers to the decreased BOLD fMRI signal in sensory regions when a stimulus is repeated and is sensitive to manipulations of attention and task demands (Yi & Chun, 2005). In pattern similiarity, researchers use multi-voxel pattern analysis to examine the similarity of the pattern of neural response to repeated presentations of a stimulus. More similarity across presentations is related to better learning (Xue et al, 2010). Though both neural measures index learning, the relationship between them is not understood, and the role of attention in pattern similarity has not been studied. Hence, we examined the relationship of these two fMRI measures. We manipulated attention by instructing participants to attend to either the face or scene dimension of composite face-scene images while performing a change detection task. Consistent with Yi and Chun (2005), we observed attenuation in the scene-sensitive parahippocampal place area (PPA) only when a scene was attended during both initial presentation and upon repetition, indicating that attention is important for repetition attenuation. Likewise, we observed more similarity between patterns of activity for repeated pairs of scenes when both instances were attended than when either or both were ignored. Additionally, there was a small positive correlation between the degree of repetition attenuation and the similarity of the pattern across repeated scenes, indicating a weak relationship between repetition attenuation and pattern similarity. We conclude that attention is important for both repetition attenuation and pattern similarity, but also that the relationship between the two measures is weak, and that they may reflect different neural properties of learning.

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26.508 **Effects of ongoing brain oscillations on psychometric functions**

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Ongoing brain oscillations in the alpha frequency range (8-12 Hz) strongly affect perception and neuronal responses to incoming visual stimuli. However, the nature of their effect on perception remains largely unknown. Mechanisms of cognitive processes that affect perception and neuronal responses – such as attention or perceptual learning – have been studied extensively by examining threshold and gain of psychometric functions. Estimation of these functions requires presenting target stimuli at different stimulus intensities. Until now, alpha oscillations have been typically studied by comparing alpha power between hits and misses in detection tasks using only a single peri-threshold stimulus intensity. Therefore, it remains elusive whether alpha oscillations modulate the threshold or rather the gain of the psychometric function. In this study, we examined the effect of pre-stimulus oscillations on psychometric functions. We tested participants' detection performance across a wide range of stimulus intensities and examined the effect of pre-stimulus brain oscillations on the slope and threshold of the psychometric function. We found that the power of pre-stimulus alpha oscillations at occipital electrodes mostly affected performance for low-intensity stimuli, making subthreshold stimuli more likely to be detected. Furthermore, alpha oscillations had stronger effects on the slope of psychometric functions than on thresholds. These results specify the role of pre-stimulus alpha oscillations and suggest that an optimal tuning of ongoing oscillations promotes sensory processing.

26.509 **Intrinsic functional connectivity of the humans lateral geniculate nucleus**

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Introduction: The lateral geniculate nucleus (LGN) is the thalamic relay between the retina and visual cortex. We sought to measure the functional connectivity between the LGN and other nearby thalamic structures, notably the thalamic reticular nucleus (TRN). The TRN receives excitatory glutamatergic input from the LGN and visual cortices and sends inhibitory GABAergic projections back to the LGN. TRN output generates spindle oscillations in the LGN, disrupting output to V1. This inhibitory complex has been observed in many animal models, but has not yet been observed in the human thalamus. Methods: The present experiment sought to observe functional connectivity in resting humans using functional magnetic resonance imaging (fMRI). Participants were scanned using a Siemens Trio 3T MRI scanner and 32-channel head coil in York University's Neuroimaging Laboratory. Anatomical regions of interest (ROIs) were generated for the LGN and TRN by manually tracing 1 hour of interpolated proton density weighted images. fMRI scans utilized an EPI sequence with a 3 coronal slices, 2mm thick, with a 128 matrix and 192 mm field of view resulting in an in-plane resolution of 1.5 x 1.5 mm2, TR = 0.251, TE = 36 ms, and flip angle of 10°. Four scans of 1200 time points each were collected in which participants were instructed to lie in the scanner with their eyes closed. The anatomically-defined ROIs were coregistered with the EPI data, and the mean time series extracted from the defined LGN mask was correlated with the entire dataset using to find functionally related voxels. Results: We observed significant correlations with the LGN and vascular structures, but not between the left and right LGN, nor with the neighboring thalamic structures. Based on these negative findings we outline multiple future strategies to examine the functional connectivity of the human LGN.

26.510 **In the zone or zoning out? Behavioral and neural evidence for distinct attentional states**

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To characterize intrinsic fluctuations in sustained visual attention, we designed a series of gradual onset continuous performance tasks (GO-CPT) to probe the relationships between reaction time (RT) variability, attention lapses, and brain activity. In Experiment 1, behavioral results confirm that the GO-CPT taxes sustained attention, as errors and RT variability increase over time. Subjects' attentional state also fluctuates moment-to-moment, with periods of higher RT variability associated with increased likelihood of errors. Using fMRI, these natural fluctuations in performance were linked to the ebb and flow of ongoing activity in the dorsal attention network (DAN) and default mode network (DMN). Specifically, moderate DMN activity accompanies less variable, less error-prone periods of "in the zone" performance. However, when "in the zone," extreme peaks in DMN are predictive of subsequent lapses of attention (errors). In contrast, when "out of the zone," reduced activity in DAN and task-relevant sensory regions predicts errors. In Experiment 2, we explored the additional effects of external distraction on sustained attention. Behavioral results provide confirmatory evidence for intrinsic fluctuations between these two attentional states. Preliminary fMRI results again suggest that lapse precursors vary with attentional state; extreme peaks in DMN (as in Exp. 1), as well as signal increases in task-irrelevant, distractor-sensitive sensory regions are particularly characteristic of errors that occur when "in the zone." Taken together, these findings highlight the neurobehavioral signatures of two distinct attentional states. The first, "in the zone," is a stable, less error-prone, perhaps effortless state, characterized by higher overall DMN activity but during which subjects are at risk of erring if DMN activity rises beyond intermediate levels, or if distractors enter awareness. The second, "out of the zone," is a potentially more effortful state that is not optimal for sustained performance and relies upon activity in task-relevant sensory and control regions.

26.511 **Three measures of ongoing neural activity examined in retinotopically mapped visual cortex**

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The brain is constantly active; neurons signal to each other even in the absence of external stimuli. Fluctuations in ongoing, non-stimulus-driven activity may modulate the brain's interaction with the external environment, and may reflect processes associated with task preparation and task maintenance. Here, we examine changes in non-stimulus-driven neural activity that reflect task maintenance and task preparation. Nineteen subjects performed auditory and visual tasks. The auditory task required discrimination between two successive sounds. The visual task required discrimination between two centrally-presented gray scale images (Gabor patches). The tasks were presented in four different behavioral conditions designed to test the effects of attention and ignoring: 1) visual task alone, 2) auditory task alone, 3) auditory task with visual distracter, 4) visual task with auditory distracter. Three types of non-stimulus-driven neural activity were measured: activity associated with maintenance of a task set, activity associated with the onset of a task block, and cue-driven activity associated with preparation for a trial of the task. Regions of interest (ROI) were created for each subject based on retinopic maps of the visual cortex. Each visual area (V1,V2, and extrastriate areas) were divided into central and peripheral ROIs depending on eccentricity. Our data show that non-stimulus-driven neural activity in the visual cortex depends on task. The pattern of these results depends on the visual cortical region and on eccentricity. Different regions show different patterns of preparation-related vs. maintenance-related ongoing activity. This indicates that these various measures reflect different mechanisms by which ongoing activity influences information processing.

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26.512 **fMRI reveals the neural basis for the distractor preview effect**

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Search for a categorical oddball is facilitated if the task-irrelevant items in the current trial are from the same category as those that comprised the prior target-absent trial (Lleras et al., 2009). In the current experiment, we investigate the neural correlated of the "distractor preview effect". During fMRI scanning, nine participants viewed three-item displays of faces and houses. On trials that contained either a single face or a single house (target), participants indicated whether a small black dot appeared to the left or the right side of the singleton. "No-target" responses were made to trials that contained no category singleton. We examined BOLD signal to target-present trials. Those trials preceded by a "target-absent trial" comprised of stimuli from the same category as the current target (i.e. a face-target trial preceded a three-face, target-absent trial) were "target preview trials" (TPT). Those trials preceded by a target -absent trial whose stimuli were of the same category as the current non-target items were "distractor preview trials" (DPT). Participants responded significantly more slowly to TPT than to DPT trials ($p < .01$). Regions traditionally associated with top-down attentional control (bilateral IPS, ACC, bilateral MFG and right FEF) were significantly more active ($p < .001$, uncorrected) by TPT than by DPT. The content of DPT and TPT were identical; their differential activation consequently reflect the state of the attentional system following trials that contained "non-target" material. To our knowledge, our work is the first to demonstrate that inter-trial changes in distractor content increases recruitment of the attentional network just as do inter-trial changes in target content (Kristjansson et al., 2007).

26.513 **Should I switch or should I focus? Switching boosts audio-visual attention**

Joaquin Rapela[1](rapela@ucsd.edu), Klaus Gramann[2], Marissa Westerfield[1], Jeanne Townsend[1], Scott Makeig[1]; [1]University of California San Diego, [2]University of Osnabrueck

You are in a forest looking for your favorite type of bird. You can search for it visually or auditorily. What is better, to focus your attention on vision for an extended period of time, and then on the audition for another extended period, or to quickly switch your attention between vision and audition? If switching is better, how quickly should you switch? Here we investigate these questions using electroencephalography (EEG) in humans performing an audio-visual target detection task. The task contained FOCUS AUDITION and FOCUS VISION blocks, where subjects had to focus their attention, for extended periods of time, on the auditory or visual stimuli, respectively. It also contained SWITCH TO VISION and SWITCH TO AUDITION blocks, where cues frequently indicated subjects to switch their attention to visual or auditory stimuli. We performed a group analysis of the spectro-temporal EEG activity of 38 subjects using Independent Component Analysis. In occipital clusters we found that: 1) the amount of alpha desynchronization (attention related activity) after a visual stimulus was larger in SWITCH TO VISION than in FOCUS VISION blocks, and the amount of alpha synchronization (lack of attention related activity -- in occipital clusters) after an auditory stimuli was larger in SWITCH TO AUDITION than in FOCUS AUDITION blocks; this indicates that the switching boosts attention respect to focusing. 2) the boosting effect was largest for the first stimuli after the switching cue (100-700 ms post cue), lower for the second stimuli (500-1400 ms), and negligible for the third stimuli (1000-2000 ms); showing that this boosting of attention decayed progressively after switching. Thus, to find your favorite bird in the forest it seems better to 1) switch your attention quickly, rather than focusing it for extended periods of time, 2) where quickly means approximately two times per second.

26.514 **Attentional control network dynamics in response to a target-similar distractor**

Nicholas DiQuattro[1,2](ndiquattro@ucdavis.edu), Risa Sawaki[2], Joy Geng[1,2]; [1]Department of Psychology, UC Davis, [2]Center for Mind & Brain, UC Davis

Stimuli in our environment compete for attention on a moment-to-moment basis. The ability to limit attention to task-irrelevant stimuli is an important aspect of behavior, but its neural mechanisms are poorly understood. Here, we used fMRI with a detection task in which targets were defined by a conjunction of color (e.g., orange) and location (e.g., on the left). The target's color was constant over blocks of trials, but its location was cued on each trial. One distracter was always present in an uncued location. The two objects appeared in one of three conditions: neutral (i.e., neither were target-colored), target-colored distracter, or target-present. On target-colored distracter trials versus neutral trials, subjects were slower to respond that the target was absent. Results showed that the right temporoparietal junction (TPJ) was more active in the target-colored distracter condition than either the neutral or target-present condition. This result is consistent with previous findings that TPJ responds selectively to behaviorally relevant, but unattended stimuli as part of the stimulus-driven "ventral attention network"(Corbetta & Shulman, 2002). In contrast, regions of the "dorsal" attentional control network, including bilateral intraparietal sulcus (IPS) and frontal eye-fields (FEF), were activated by all conditions and correlated positively with RT. A correlational analysis of beta parameters taken from TPJ and IPS showed a negative correlation at the onset of the target location cue, but a positive correlation during the stimulus presentation. This suggests that TPJ is suppressed at the time of top-down attentional deployment in response to the spatial cue, but works with dorsal network regions (e.g., IPS) when an unattended stimulus may potentially contain critical information. Additional connectivity analyses conducted to further quantify the dynamics between TPJ and IPS demonstrated that the "dorsal" and "ventral" networks dynamically interact to control attention to reject distracters and select targets.

Acknowledgement: UC Davis

Attention: Spatial I

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

26.515 **Stronger Inhibition of Return Revealed for Identification Accuracy in the Presence of High External Noise**

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Spatial cuing usually improves response time in a detection task when the target location is cued a fraction of a second before stimulus onset. However, as cue and stimulus onset asynchrony increases, there is a range of SOAs where cuing worsens response time, a phenomenon called inhibition of return (IOR; Posner & Cohen, 1980, 1984). There is disagreement over whether IOR occurs for identification tasks as it does for simple response time tasks (e.g., Terry, Valdes, & Neill, 1994; Cheal, Chastain, & Lyon, 1998). Few researchers have studied IOR with an identification accuracy measure (e.g., Cheal & Chastain, 1999). Traditional spatial cuing effects on accuracy, with short cue-target SOAs, are more often found when targets are obscured by external noise, reflecting improved external noise filtering in attended conditions (e.g., Dosher & Lu, 2000). We hypothesized that IOR in identification tasks may be stronger in the presence of high external noise. We performed an identification task manipulating cue-target SOA (100-1200 ms) and contrast in the presence or absence of external noise, and measured both accuracy and response time. Observers each performed 9218 trials, and were analyzed individually. Attention filtering factors were estimated for each SOA. As in traditional cuing, larger cuing effects occurred in the high external noise condition. Two observers also showed evidence of IOR, with cuing effects on accuracy in low SOAs dissipating or reversing at higher SOAs; a third observer showed no consistent cuing effects on accuracy. We found little or no traditional cuing or IOR in low external noise, where IOR is usually tested. The cuing effect in response time was more variable, but generally consistent with accuracy results. Our results suggest that IOR in identification tasks is more likely to occur in the presence of high external noise, where attention may have stronger effects on accuracy.

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26.516 **Endogenous attention optimizes performance by adjusting spatial resolution: evidence from selective adaptation**

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GOAL. In texture segmentation tasks constrained by spatial resolution, exogenous (involuntary) attention improves performance at peripheral locations where resolution is too low, but impairs performance at central locations where resolution is already too high (central performance drop, CPD). Exogenous attention automatically increases resolution at all eccentricities by increasing sensitivity of high spatial frequency filters. Conversely, endogenous (voluntary) attention benefits performance across all eccentricities, suggesting a flexible mechanism that optimizes performance. Can endogenous attention flexibly adjust resolution as a function of eccentricity? If so, how? Alternatively, does endogenous attention benefit performance across eccentricity through means other than adjusting resolution (e.g., increasing signal-to-noise ratio)? METHODS. To investigate the mechanisms underlying the effects of endogenous attention on texture segmentation, we combined a cueing paradigm with selective adaptation. After adapting to either high or low spatial frequency patterns, observers reported the presence or absence of a target that could appear at several eccentricities in a texture display. Central valid precues directed voluntary attention to the upcoming target's location. Postcues ruled out location uncertainty. Attention effects were evaluated against a neutral precue condition; adaptation effects against a control condition (no spatial frequency modulation). RESULTS. Selective adaptation to high or low spatial frequencies affected performance compared to the control condition. Adapting to low spatial frequencies resulted in a more pronounced CPD and a shift of the performance peak towards more peripheral locations. Conversely, adapting to high spatial frequencies diminished the CPD and shifted the performance peak towards central locations. Moreover, adapting to high, but not to low spatial frequencies, eliminated the attentional benefit at central locations. These results suggest that endogenous attention flexibly adjusts spatial resolution. Endogenous attention optimizes performance across all eccentricities, either enhancing or decreasing resolution, and does so by adjusting the sensitivity of high spatial-frequency filters.

Acknowledgement: NIH R01-EY016200

26.517 **Understanding the failures of selective attention: The flanker congruency effect is consistent with failures of selection not perceptual interactions**

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Flanker congruency experiments show that an irrelevant stimulus can affect the judgment of a second, relevant stimulus. It is unclear whether this effect is due to dependencies between the processing of relevant and irrelevant stimuli before selection, or due to failures of selection on some fraction of trials. In order to investigate the cause of the flanker congruency effect, we combined the flanker and spatial filtering paradigms. As in the flanker paradigm, we mapped a set of colored disks to different response sets creating congruent and incongruent conditions; as in the spatial filtering paradigm (Yigit-Elliott, Palmer, & Moore, 2011), we presented a target and a flanker in the periphery as opposed to presenting the target near the fovea and the flanker in the periphery. This way, the target and flanker were interchangeable, and only differed in location. This assures that any congruency effect is due to selective attention rather than sensory processes alone. We varied the contrast to measure psychometric functions and examined both large and small separations between the target and flanker (1° or 11.3°). There were three critical conditions: the target and flanker were identical (identical); the target and flanker required the same response (response congruent); and, the target and flanker required different responses (response incongruent). For large separations, accuracy was the same for all conditions. For small separations, accuracy was the same for the identical and response congruent conditions. The flanker congruency effect was found only in the response incongruent condition and only on the asymptote of the psychometric function. The threshold was the same in all conditions when defined relative to the asymptote. These results are consistent with a theory that assumes all-or-none selection and independent processing before selection. In such a theory, the stimulus that is not selected (unattended) has no effect on behavior.

26.518 **The spatio-temporal profile of attention to targets in texture**

Preeti Verghese[1](preeti@ski.org), Saeideh Ghahghaei[1]; [1]Smith-Kettlewell Eye Research Institute, San Francisco

Attention is important for selecting targets for action. Several studies have shown that attentional selection precedes eye movements to a target, and results in an enhanced sensitivity at the saccade goal. Typically these studies have used isolated targets on unrealistic blank backgrounds. We examined how the spatial profile of sensitivity changes when the target is presented on a textured background. We also measured the sensitivity profile at different times before the saccade to determine how the influence of the surrounding context develops over time. A central cue indicated which one of two potential targets on the left or right of fixation was the saccade target. The targets appeared alone, or on one of 2 textured backgrounds: a single uniform texture, or a concentric arrangement of 2 textures with orthogonal orientations. The cue lasted 300 ms and its offset served as the saccade-go signal. A dim, brief probe was presented before the saccade occurred and observers judged whether it appeared above or below the target. Both the spatial position of the probe and its delay with respect to the cue were varied. To ensure that observers accurately planned a saccade to the target, a post-cue indicated which one of two tasks to perform: an increment detection task on the target or a report of probe location. When the target was on a blank background or a uniform textured background, spatial sensitivity peaked at the target location about 300 ms after cue onset and declined with distance from the target. However, when the background was made up of an inner and outer texture, sensitivity to the inner texture was transiently increased at latencies typically required for the segmentation of orientation-defined textures. Thus our results indicate that spatial selectivity around the target interacts with other processes that group and segment the visual scene.

26.519 **The role of motor response in feature repetition priming: Encoding of search-relevant information is not contingent on links between features and motor responses.**

Amit Yashar[1](amityash@gmail.com), Tal Makovski[2], Dominique Lamy[1]; [1]Tel Aviv University, [2]University of Minnesota

It has become widely acknowledged that our goals and actions greatly influence the representation of our visual world. For example, simple motor actions, such as pointing or grasping, can modulate the way we perceive and attend to our visual environment. In the present study we investigated the role of motor responses in the modulation of attentional allocation by implicit short-term memory. Numerous studies have demonstrated that what we attend to at a given time affects how our attention is deployed in the few moments that follow. For instance, Maljkovic and Nakayama (1994) showed that when searching for a discrepant target among homogenous distractors, performance is better when the target and distractors features remain the same than when they switch, an effect known as priming of pop-out (PoP). We recently showed that in addition to attentional processes PoP affects motor response preparation/selection (Yashar & Lamy, 2011). Here we demonstrate that motor response is not necessary for encoding of search relevant attributes in pop-out search. In three experiments, observers

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searched for a colored singleton target. On response-trials, they responded to the target's shape, whereas on no-response trials, they passively looked at the display. Observers were faster to respond when the color of the target repeated from the previous to the current trial, even when the previous trial was a no-response trial. This effect resulted mainly from distractor inhibition, and disappeared when the display in the no-response trial lingered for 1000 msec. These results suggest that the process of encoding search-relevant attributes in pop-out search is automatic and is not contingent on the production of a motor response. These findings are inconsistent with claims that repetition of search-relevant attributes in visual search mainly affects response-related processes.

26.520 **Attentional sets interact with load but not with dilution**

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The theory of perceptual load (Lavie & Tsal, 1994; Lavie, 1995) proposes that the processing of irrelevant distractors is prevented only when high load in relevant processing exhausts attentional resources. The theory has been supported by a line of experiments presenting conditions of high and low-load in separate blocks, resulting in processing of to-be-ignored stimuli in the low load condition but not in high load conditions. Theeuwes, Kramer, and Belopolsky (2004), showed that when high-load and low-load displays are randomly intermixed, the processing of to-be-ignored stimuli is similarly obtained under both conditions, suggesting that: 1) attentional sets affect selectivity 2) high perceptual load is not sufficient for effective selectivity. Recently, Tsal and Benoni (2010; Benoni & Tsal, 2010) argued that the common use of display size confounds perceptual load with the factor of dilution (produced by the neutral items present in high load displays). In a series of experiments which separated the possible effects of load and dilution, they demonstrated that it is dilution, not load, affecting the efficiency of selection. The results obtained in Theeuwes at el., 2004 questions perceptual load theory but also challenges the dilution account, which offers an alternative underlying bottom-up mechanism. In the present study we separated the effects of dilution and load by adding dilution displays, that were low in perceptual load but high in dilution, we tested the influence of attentional sets, by comparing mixed and fixed blocks for low-load, high-load, and dilution displays. We found that attentional sets interacted with load but not with dilution. Thus, the dilution effect is preserved across fixed and mixed presentations and is not influenced by expectancy of trial type. The results are discussed within the framework of a new general task difficulty account.

26.521 **Rapid acquisition but slow extinction of an attentional bias in space**

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Introduction. The complexity of our visual environment entails selectivity in visual processing. Previous research suggests that spatial orienting is driven by salient stimuli or an observer's goal. However, in the real world, one's previous experience frequently directs spatial attention, often in an implicit manner. How does implicit learning affect the spatial orienting of attention, and is implicitly learned attention a distinctive form of attention? Methods. To characterize implicitly learned attention, we examine its long-term persistence and sensitivity to cue validity. In a location probability learning task, participants searched for a T target among L distractors. Unbeknownst to them, across multiple trials, the target was more often located in one region of the screen than in others. Learning was reflected by faster RT when the target fell in the rich rather than the sparse locations. Results. An attentional bias toward the rich locations developed rapidly over dozens of trials at the beginning of training. However, once a bias existed, it was slow to adjust to new statistical contexts. These biases persisted for at least a week and for hundreds of trials after the target's location became evenly distributed, even when new visual statistics made use of the learned attentional bias costly, and despite explicit knowledge that the learned bias was no longer valid. However, learned spatial biases did not always dominate spatial attention once they were acquired. The learned spatial bias did not transfer between different tasks, such as visual search and change detection. Furthermore, the learned spatial bias was substantially weakened by an endogenous cue (such as a central arrow) that varied from trial to trial. Conclusion. Long-term persistence differentiates implicitly learned attention from the more flexible goal-driven attention. It also suggests that visual statistical learning does not always reflect the true statistics of the environment.

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26.522 **Successful Countermanding Affects Presaccadic Attention at the Saccade Goal**

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It is well known that prior to a saccade, attention shifts to the saccade goal, improving perceptual discrimination at that location. Here we investigated subjects' ability to shift attention during a saccade countermanding task, in which they were asked to stop the execution of a saccade for a portion of trials. We hypothesized that stopping the saccade may disrupt the attentional shift to the saccade goal location. Ten subjects discriminated a letter at one of 6 target locations and at the same time performed saccades as fast as possible to one these locations as indicated by a central arrow. A discrimination letter flashed during the saccade latency either at the arrow location 50% of the time (congruent condition) or randomly at one of the other 5 target locations (incongruent condition). During Stop trials (25% of trials), the central arrow turned red, indicating to subjects not to make a saccade; the central arrow turned red at different delays (0-150ms) after it appeared (stop signal delay - SSD). The longer the SSD, the less able subjects were at stopping the saccade. For successful Stop trials, discrimination performance was significantly better in the congruent condition (60%) compared to the incongruent condition (39.8%). However, for the congruent condition, performance was much lower than that of successful Go trials (78.6%). Performance was also significantly lower than performance in the congruent condition in a covert attention control without eye movements (80.2%). In summary, while there still remains a certain amount of attention at the saccade goal when the saccade is stopped, it is greatly reduced compared to when it is not stopped or when a saccade is never required. These results suggest that stopping a saccade affects the attention shift to that location and that attention is disrupted by saccade inhibition processes.

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26.523 **Pre-saccadic perceptual facilitation: top-down covert shift of attention or automatic enhancement of visual processing?**

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Immediately before making an eye movement discrimination performances at the saccade goal is improved. Is this facilitation top-down covert attention or an automatic enhancement of visual processing? We compared the performance of ten subjects in identifying a target letter (b,d,p,q, 4AFC) in their upper or lower visual field (2 possible target locations at 7° eccentricity on the vertical meridian) both in a covert attention task and while planning a saccade, in both cases guided by a central arrow cue. Because we suspect that better performance in the lower visual field is a marker for covert attention, we ask whether the same bias is present for the pre-saccadic facilitation. To investigate the top-down influences, we manipulated the cue validity probability. When the cue validity was 90%, there was a clear lower field preference in the pre-saccadic letter identification performance that correlated strongly with the bias observed in the covert attention condition, suggesting that pre-saccadic facilitation could be mainly due to covert attention. However, with 50% and 10% cue validity, performance in the covert and pre-saccadic conditions differed. Covert performance followed the cue validity (i.e. attention was allocated according to the probability of target appearance, not simply the cue direction). Pre-saccadic discrimination remained better at the cued location (saccade target), despite showing improvement at the non-cued location as cue validity decreased. Importantly, the lower field preference was not present for discriminations away from the saccade target (invalid trials) and therefore the bias was de-correlated from the covert performance. In summary, reducing cue validity induces a dissociation between covert attention and pre-saccadic facilitation, breaking the lower field bias. We conclude that pre-saccadic facilitation is an automatic processing enhancement that can be combined with additional covert attention.

26.524 **Dilution and redundancy effects on Stroop interference**

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It is well known that visual objects belonging to the same perceptual category compete for category-specific, limited-capacity attentional resource. However, it remains to be seen how perceptually identical objects interact with each other during visual analyses. Two perceptually identical objects might compete with each other as much as two different objects of a category. Alternatively, they might cooperate to form a stable, veridical representation. These conflicting possibilities were tested with three behavioral experiments. Experiment 1 and 2 used a name-picture Stroop task. In each trial, participants categorized a famous target name into that of an actor or a sports player while ignoring a flanking famous face distractor, which could be either congruent (e.g., an actor's name and face) or incongruent (e.g., an actor's name and a player's face). In some trials, either the same face or an unknown face was added in the opposite side of the face distractor. As results, relative to a single distractor, Stroop interference was reduced by two different distractors ("dilution effect") while it was enhanced by two perceptually identical distractors ("redundancy effect"). Importantly, this redundancy effect disappeared when two faces were the same at the response level, but different at the perceptual level. These results were replicated with nonface objects in Experiment 3, which further showed that neither dilution nor redundancy effect was affected by the between- vs. within-hemisphere distractor presentations. Our findings indicate that both dilution and redundancy effects may be mediated by perceptual representations based on hemisphere-independent attentional resources. In addition, both effects here support the hypothesis that Stroop interference arises through parallel attentional selection processes, rather than the deployment of a single attentional focus.

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26.525 The head turn cueing effect is sustained at longer SOA's in the presence of an object distractor

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In social cueing studies, participants are asked to discriminate a target object cued by social signals, such as eye gaze or head turns. Knowing that the cues are not predictive, participants nevertheless respond faster to the target presented at the cued than uncued location at short Stimulus Onset Asynchrony (SOA) intervals of 300 to 600 ms. However, as the SOA between the cue and target increases (1005 ms), the cueing effect diminishes indicating that the reflexivity of social cues can be overridden by voluntary, controlled processes.In the current study, we tested the reflexive and voluntary characteristics of social cues in an object recognition task. In our paradigm, participants were asked to discriminate a circle or square target object appearing in the left or right hand of a human model. On half of the trials, a distractor triangle object appeared in the opposite hand and on the other half of the trials, no distractor object was presented in the opposite hand. The target object was cued by a head turn that appeared at SOA's of 0, 105, 300, 600 or 1005 ms. Participants had to report which target they saw by key press and were told to ignore the head turn because it had no predictive validity. Without a distractor, the typical results were found where a cueing effect was evident at SOAs of 300 and 600 ms and disappeared at the longer 1005 ms SOA. However, in the distractor present condition, a cueing effect was found at the 300, 600 and critically, remained potent at the SOA of 1005 ms. These results call into the question of the reflexive-voluntary account of social cueing effect and suggest that, in the presence of a distractor object, head turn cues cannot be voluntarily inhibited at the long SOA.

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26.526 Spatial probabilities modulate repetition effects in target detection

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Previous studies have demonstrated that both implicit spatial probabilities and repetition priming facilitate perceptual processing: targets in high probability or repeated locations are detected more rapidly and accurately. In this study we examined the relative contributions of spatial repetition priming and implicit spatial probabilities on target detection. Eight possible target locations were arranged in a circle, which subtended 4° of visual angle. On each trial, 4, 6, or 8 objects appeared within designated locations for 250 ms; the target was always present. Subjects reported the location of the target in an 8-alternative forced-choice localization task using a computer mouse. Targets appeared in the high probability location on 30% of trials and were evenly divided amongst the other 7 low probability locations on the remaining 70% of trials. Central fixation was monitored throughout the display period. The results showed that target detection performance (accuracy and RT) was at ceiling across all set sizes in the high probability location, but there was a linear decrease in performance across set sizes for targets in the low probability locations. There was also an interaction between spatial probabilities and repetitions: There was no effect of repetition for targets in the high probability location (perhaps due to ceiling effects in performance), but detection of repeated targets in low probability locations was actually worse. When subjects mislocalized the low probability targets, they tended to select a nearby location away from the high probability location. This suggests that spatial probabilities may serve as a "top-down" modulation of the prepotent "bottom-up" bias for targets in repeated locations. We speculated that spatial probability distributions do so by biasing limited-resource search mechanisms that control spatial attention.

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26.527 When Information Matters: The Effects Of Cue Predictability And Distractors On The Allocation Of Attention

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We investigated how cue predictability affects reaction time (RT). We manipulated number of locations, the presence of distracters and the amount of information (in bits) provided by the spatial cues. In each experiment, a trial began with a fixation field, followed by a central cue, and finally a target letter. In Experiment 1, we varied cue information by varying the number of target locations. In separate blocks, there were either two or six possible target locations. On half of the trials, a noninformative cue (a + sign) was presented. On the remaining trials an arrow cue was 100% predictive of target location, corresponding to 1 and 2.58 bits of information in the two and six location displays respectively. We found that although the cue had a significant effect on RTs, the cueing effect did not vary as a function of information. Experiment 2 was an exact replication of Experiment 1 except that we added distractors that appeared in nontarget locations. In this experiment, the cueing effect was significantly larger with six locations than with two locations. Thus with distractors, attention was modulated by the information provided by the cue. Last, we parametrically investigated this effect. On some trials, the target appeared in the cued location (valid) and on some trials it indicated a nontarget location (invalid). The proportion of valid trials varied across session. There were four levels of cue predictability corresponding to 0.0, .51, 1.02, and 1.55 bits of information. We found that the relation between the cueing effect in RT and information provided by the cue was linear. In summary, in the absence of distractors, effects of cue predictability were similar regardless of the amount of cue information. In contrast, when distractors were present, as cue information increased, so did the RT cueing effects.

26.528 Attentional Filtering and Friend vs. Foe Discrimination in Action Video Games

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Playing first-person shooter (FPS) video games has been shown to improve performance in a number of visual tasks (e.g., Green & Bavelier, 2003). Here we ask whether a specific aspect of FPS games (friend vs. foe discrimination) might be responsible for some of these improvements. Non video game players were identified using a covert assessment strategy and invited to the study. On Day 1, all participants completed a pre-test consisting of the filter, visual working memory, and flanker tasks and then were assigned to one of three groups: no training, friends and foes, or foes only. The no training group returned on Day 4 to take the post-test consisting of the same tasks as the pre-test. The friends and foes and foes only groups played custom designed video game levels for two hours (30 minutes on Day 1, and 45 minutes on Days 2 and 3) before taking the post-test on Day 4. In the friends and foes condition, half of the characters in the game world attacked the player and the other half ran up to and attempted to follow the

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player. In the foes only condition, all characters attacked the player. The player's task was to eliminate all enemies (without shooting friends) and then progress to the next room. The game world consisted of 16 rooms that progressed in difficulty. Preliminary results indicate that filter task performance for the friends and foes condition was significantly better than the no training condition ($p < .01$) and marginally better than the foes only condition ($p = .083$) though training condition did not interact with time. Additionally, participants in the friends and foes condition showed a decrease in flanker interference that was marginally larger than the decreases in the foes only ($p = .104$) and no training ($p = .054$) conditions.

26.529 Handcuffing visual attention: Selection is narrowed and slowed near the hands

Christopher Davoli[1](chris.davoli@gmail.com), James Brockmole[1]; [1]Department of Psychology, University of Notre Dame

Perception, attentional control, and working memory are remarkably influenced by the proximity of the hands to viewed objects. For example, items near the hands receive perceptual, attentional, and memorial priority relative to other objects in the environment. Nevertheless, it remains unclear what mechanism underlies these effects. Here, we propose that the priority given to information near the hands arises because (1) attention is less susceptible to interference from information outside of hand-space, and (2) voluntary shifts of attention between dimensions on which objects may be analyzed (e.g., global shape, local elements) are relatively slow and inflexible near the hands. We tested this hypothesis in two studies. In Study 1, participants performed an Eriksen-type flanker task while holding their hands either around the target, such that the flankers appeared outside of hand-space, or with their hands off to the side and thus not around any of the stimuli. We found that flanker interference was substantially reduced when the hands were held around compared to not around the target. A control condition confirmed that this reduction in interference was not observed when non-hand physical barriers were placed between the target and flankers. In Study 2, participants analyzed objects according to their global shape or local elements while holding their hands near to or far from the objects. Across subsequent objects, participants either maintained the same attentional scope or switched between global and local processing. We found that switches between global and local processing were markedly slowed near the hands. Together, these findings indicate that previously observed alterations in visual processing might be attributed to a mechanism of attention that is resistant to intrusions from external information and to effortful shifts of attention, thereby allowing observers to more deeply "lock in" to processing of objects within the hands.

26.530 Time course of visual orienting to subliminal central events

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A number of recent experiments demonstrated the role of subliminal peripheral events in orienting visuospatial attention (see Mulckhuyse & Theeuwes, 2010 for review). In our earlier experiments (Vakhrushev & Utochkin, 2011), we found out that subliminal central cues (briefly presented faint arrows) can also cause shifts of attention towards cued locations yielding slight but significant acceleration of target detection. In that study, we tested effects of valid vs. invalid cues at two SOAs of 200 and 500 ms and found a cue benefit at 500 ms. In the present study, we investigated subliminally-driven orienting more accurately by introducing neutral condition and using four SOAs of 200, 400, 600 and 800 ms. 26 participants performed speeded detection of a target to the right or left from fixation. Targets were preceded by brief warning signals (clearly visible squares around fixation point). Concurrently with the squares, faint (subliminal) arrow cues appeared at fixation. Cues could be valid (70% target trials), invalid (15%), or neutral (no arrow, 15%). Catch trials (20% of total number) were introduced to control anticipatory responses. Cues subliminality was controlled by postexperimental arrow discrimination test that yielded performance below chance. In the result, it was found no cue effects at 200-ms SOA and significant advantage of valid over invalid condition at 400-ms SOA that is consistent with our earlier results (Vakhrushev & Utochkin, 2011). At 600-ms SOA, we found advantage of both valid and invalid conditions over neutral one. The two possible explanations are discussed. First, it may be elicited by nonspecific arousal effect of subliminal stimulation on reaction time. Second, it may reflect late attentional distribution among two potential target locations following earlier focusing at only one cued location at 400 ms. The future experiments will be conducted to distinguish between these two explanations. Finally, there was no cue effect at 800-ms SOA.

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Eye movements: Cognition

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

26.531 The effects of potential social interactions and implied social presence on social attention

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We have conducted two studies demonstrating that looking behaviour is modified by (a) the potential for a social interaction, and (b) the implied social presence of another. The way that we attend to socially relevant stimuli has traditionally been studied using rather impoverished paradigms that preclude the opportunity for social interaction. This presents a scenario that fails to mimic what we experience in day-to-day social situations. In a between subjects design, participants wearing eye trackers were told to wait in a room that had either a video of a confederate completing a questionnaire, or a real life confederate completing a questionnaire. People looked significantly more frequently at the video confederate than at the live confederate, suggesting that shifts in social attention that occur as a result of being immersed in a complex real-life environment do not map on to those that occur in more typical experimental settings. A related concept emerged when participants were asked to complete an irrelevant computer task in a room that contained a swimsuit calendar. Participants wearing an eye tracker looked at the calendar far less frequently than those not wearing an eye tracker, which begs the question: is eye tracking data failing to capture what people really look at? Collectively, these data have important theoretical and practical implications. They also raise immediate questions for future investigation. For instance, did the presence of an eye tracker in study 1 contribute to the tendency for participants to look away from the live confederate? Additionally, will the implied social presence of an eye tracker affect the moral behavior of individuals in ways other than looking at sexy calendars? For instance, will people be less prone to cheat?

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26.532 Animated character appearance affects viewing patterns and subjective ratings of personality characteristics

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Animated characters are frequently used in television programs, movies, and video games, but relatively little is known about how their characteristics affect attention and viewer opinions. We used eyetracking to examine the role of visual complexity, animation style, and motion complexity on viewing patterns and ratings of videorecorded and animated movie clips. We created twelve sets of videos using HD recording and animation methods. Each set consisted of four videos of an actor performing and describing a series of actions with blocks that resulted in a design. Of the videos, one was a regular HD recording of the actress (Video condition). The remaining videos were animated using motion capture (MoCap) data from that actress: (1) a 3d-rendered, photorealistic human character created to look like the actress (Virtual) animated using high-density facial MoCap data; (2) a 2d-rendered, cartoon-style human character that was created by toon-rendering the virtual character, using the same data (Cartoon); and (3) a 3d-rendered, photorealistic robot character animated using only a small subset of the facial motion capture data (Robot). This method ensured that motion characteristics were controlled while visual factors were varied. Participants answered questions about each video and the characters. There was a significant effect of character style on the percentage of video time spent viewing the face such that viewers looked least at the face of the robot followed by the video, cartoon, and virtual characters. Increased facial looking time correlated with unpleasantness and repulsiveness ratings. Overall ratings showed that the characters differed on how lifelike, likable, and creepy they were. In conclusion, animation styles have an effect on both viewing patterns and audience members' subjective opinions of characters.

Acknowledgement: NSF Grant 0811450

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26.533 **Looking from different viewpoints:** an eye movement study on novel object and face recognition.

Filipe Cristino[1](f.cristino@bangor.ac.uk), Candy Patterson[1], Charles Leek[1]; [1]Wolfson Centre for Clinical and Cognitive Neuroscience, School of Psychology, Bangor University

Eye movements have been widely studied, using images and videos in laboratories or portable eye trackers in the real world. Although a good understanding of the saccadic system and extensive models of gaze have been developed over the years, only a few studies have focused on the consistency of eye movements across viewpoints. We have developed a new technique to compute and map the depth of collected eye movements on stimuli rendered from 3D mesh objects using a traditional corneal reflection eye tracker (SR EyeLink 1000). Having eye movements mapped into 3D space (and not on an image space) allowed us to compare fixations across viewpoints. Fixation sequences (scanpaths) were also studied across viewpoints using the ScanMatch method (Cristino et al. 2010, Behavioural and Research Methods, 42, 692-700), extended to work with 3D eye movements. In a set of experiments where participants were asked to perform a recognition task on either a set of 3D objects or faces, we recorded their gaze while performing the task. Participants either viewed the stimuli monocularly or stereoscopically as anaglyph images. The stimuli were shown from different viewpoints during the learning and testing phases. A high degree of gaze consistency was found across the different viewpoints, particularly between learning and testing phases. Scanpaths were also similar across viewpoints, suggesting not only that the gazed spatial locations are alike, but also their temporal order.

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26.534 **Gaze patterns during observation of emotional bodily movements reveal individual lateral biases**

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INTRODUCTION: Previous work has revealed a lateral asymmetry in the production of emotional body language, consistent with related observations in faces: The left body half (LBH) moves with higher motion energy and amplitude, and is also perceived as more expressive (Roether et al. Curr. Biol., 2008). We tested whether this lateral asymmetry influences the looking behavior during the observation of emotional body stimuli by recording the associated eye movements. METHODS: Based on motion-capture data from emotional walks we created three sets of stimuli: 1) normal walks showing higher motion energy of the LBH; 2) stimuli mirrored about the horizontal symmetry axis, for which the movements of the right body half (RBH) were more expressive; and 3) perfectly symmetric chimeric walks created by presenting the movements of the LBH on both body sides. Participants performed an emotion classification task during which their eye movements were recorded. Fixation durations were determined separately for the LBH and RBH of the displayed avatars. The gaze bias (%fixation: left versus right) for each participant was calculated for different emotions, and walkers, followed by a cluster analysis of the obtained gaze biases. RESULTS: For all participants there was an almost significant trend to look more at the LBH: $F(1,20)=3.81$, $p=.065$. Between subjects, we found three different types of oculomotor response patterns that were associated with different gaze biases. The performance for the classification task between these groups did not significantly differ. CONCLUSIONS: Unexpectedly, we found three different gaze strategies that varied between participants. Those strategies were consistent over the three walker types (normal, mirrored, chimerical) and emotions. They reflect thus a general personal gaze preference rather than an influence of the saliency of emotion-specific features. In addition, there appears to be a tendency to look longer at the LBH than at the RBH.

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26.535 **Mind the curve: What saccadic curvature can tell us about face processing**

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There is a bias to look at other people's faces. What drives this bias is unclear, however, and there is debate in the literature regarding whether upright faces capture attention more strongly than do inverted faces, or whether faces are processed more effectively by one hemisphere over the other. To investigate how faces attract attention, we adapted a traditional saccadic trajectory task. The examination of saccadic trajectories is well suited to exploring how attention is deployed to different face stimuli, as saccades aimed to target objects will show characteristic curvature in response to nearby distractor stimuli. When saccades are executed rapidly, a distractor will cause the saccades' trajectory to curve towards the distractor's location, indicating that it has captured attention. In contrast, when a saccade is executed more slowly, its trajectory will curve away from a distractor, suggesting that the object has been inhibited in order to better accommodate target selection. Further, the magnitude of a saccade's curvature is determined in part by the saliency of the distractor: the more salient the distractor, the greater the curvature. With this in mind, we asked participants to make saccades to vertical targets in the presence or absence of task-irrelevant distractor faces (upright or inverted, presented in the left or right visual hemifield). Somewhat unexpectedly, face orientation did not strongly influence saccadic trajectory, suggesting that in this context, inverted faces capture attention as much as upright faces. Interestingly, presentation location did matter: faces presented in the left hemifield produced greater deviation away from the distractor than did faces presented in the right hemifield. Future studies are aimed at better understanding the implications of this effect and whether it is specific to faces.

26.536 **The relationship between overt attention and event perception during dynamic social scenes**

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When watching people perform everyday activities such as doing laundry viewers spontaneously segment the activities into a sequence of events. The timing of these event boundaries are surprisingly consistent across viewers. Neuroimaging evidence suggests that this consistency across viewers may be due to the use of changes in motion to identify points at which prediction error about the future form of an event rises above threshold and signals the beginning of a new event (Zacks et al, Nature Neuroscience; 2001). Brain regions thought to be associated with attentional control are also selectively active during event boundaries. Do changes in motion at event boundaries capture overt attention and can the gaze behaviour across viewers be used to predict event segmentation? In this study, participants viewed videos depicting an actor performing an everyday task (laundry, washing a car, or building a tent) while their eye movements were recorded. Participants initially free-viewed each video then subsequently watched the videos again while either parsing them into the smallest (fine) or largest (coarse) units that seem natural and meaningful. Analysis of gaze behaviour during free-viewing indicated significantly greater clustering of gaze across participants at fine event boundaries but less clustering at coarse boundaries. As previously reported, fine boundaries appear to be associated with changes in motion of the actor's hands and our results confirm that this relationship can also be observed as an increase in gaze to the hands and greater gaze clustering across viewers. These results both confirm the spontaneous segmentation of human events during free-viewing, and suggest the role overt attention and expectation play in parsing the flow of information in naturalistic dynamic social scenes.

26.537 **The Death of of General Wolfe: Investigating the influence of artistic compositional techniques on eye movement control and interpretation of paintings**

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Research in natural scene perception has demonstrated the involvement of both saliency and cognitive control in directing gaze patterns (Parkhurst et al., 2002; Henderson et al., 2007). In paintings, the artist has control over both the salient and semantic aspects of the "scene". For example, artistic techniques such as brush strokes are used to add texture, increase salience and guide gaze to the artistic center of focus (Enns et al., 2010). In the current study, we used three versions of the painting "The Death of General Wolfe" by artist Benjamin West (1738-1820) as stimuli. All these versions represent the same scene with slightly different compositions between versions – new background, changes in brightness and textural details and their locations. While all versions share a common central salient region, the number of additional salient regions varies. Using the Wolfe paintings, we investigated whether an artist can manipulate salience through compositional differences to induce different interpretations across versions. Three groups of participants (n=16/group) viewed one version of the Wolfe painting along with five filler paintings while their eye movements were tracked. Results indicated a significant difference in overall fixation duration (F (2,310)=4.57, p=0.01) between versions of the Wolfe paintings that was not present in filler paintings. Additionally, there was a difference in the dispersion between versions during the initial examination of the painting (first five fixations) (F (2,12) = 42.89, p<0.001). These results suggest that artists can differentially guide viewer gaze while maintaining the same semantic information. We hypothesized that changes in number of salient regions that affect gaze may also affect the perceived importance of accompanying figures in the painting. Further research will investigate whether differences in eye movement patterns result in subtle interpretation differences across versions of the painting.

26.538 **Dysmetric saccades to targets moving in predictable but nonlinear trajectories**

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A saccadic eye movement to a moving object requires taking both the object's position and velocity into account. While recent studies have demonstrated that saccades can do this quite well for linear trajectories, its ability to do so for stimuli moving in more complex, yet predictable, trajectories is unknown. With objects moving in circular trajectories, we document failures of saccades not only to compensate for target motion, but even to saccade successfully to any location on the object trajectory. While maintaining central fixation, subjects viewed a target moving in a circular trajectory at an eccentricity of 6, 9, or 12 deg for 1-2 sec. The stimulus orbited fixation at a rate of 0.375, 0.75, or 1.5 revolutions/sec. The disappearance of the central fixation point cued the saccade. Quite unexpectedly, the circularly moving stimuli substantially compromised saccade generation. Compared with saccades to non-moving targets, saccades to circularly moving targets at all eccentricities had substantially lower amplitude gains, greater curvature, and longer reaction times. Gains decreased by 20% at 0.375 cycles/sec and more than 50% at 1.5 cycles/sec. Reaction times increased by over 100ms for 1.5 cycles/sec. In contrast, the relationship between peak velocity and amplitude was unchanged. Given the delayed nature of the saccade task, the system ought to have sufficient time to program a reasonable voluntary saccade to some particular location on the trajectory. But, the abnormal gain, curvature, and increased reaction time indicate that something else is going on. The successive visual transients along the target trajectory perhaps engage elements of the reflexive system continually, possibly engaging vector averaging processes and preventing anticipation. These results indicate that motor output can be inextricably bound to sensory input even during a highly voluntary motor act, and thus suggest that current understanding of reflexive vs. voluntary saccades is incomplete.

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26.539 **Planning of saccadic eye movements in an evaluation task**

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We investigated eye movements in a simple evaluation task. On each trial, two compositions were sequentially presented for 3s each and observers indicated which of the two was more attractive. Inspired by the painter Kandinsky, we used stochastically-generated compositions that consisted of three large black disks and five small black disks on a white background. Methods. We tracked observers' eye movements while they viewed each composition with an Eyelink1000 eyetracker. We systematically varied the centers of gravity (COG) of compositions to see how COG affected the saccadic pattern. We also presented each composition and its three reflections around horizontal and vertical axes. This symmetry manipulation allowed us to assess the relative importance of deterministic and random factors in planning saccades. If saccadic patterns evoked by symmetric compositions were themselves symmetric, we would conclude that saccadic planning is determined by the composition. We characterized the subject's exploration by computing the convex hull area (CHA) of saccadic endpoints with increasing number of saccades within a composition. Each observer completed 192 = 4x48 trials. Five observers participated. Results: The mean number of fixations per composition was 8.1. COG. Surprisingly, the mean location of first saccades did not fall near the COG. Rather it fell on a line joining the center to the COG, approximately 40% percent of the way to the COG, depending on observer. The mean second saccade fell approximately on the COG. Symmetry. By several metrics, saccadic patterns for the third and later saccades for compositions related by symmetry were markedly more similar than those for unrelated pairs CH area. As few as four saccades could achieve the maximum possible CHA. Surprisingly, we found a gradual, nearly linear increase of CHA over all saccades. We conjecture that the visual system thereby controls the flow of information into working memory.

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26.540 **Target predictability and eye-hand coordination in a rapid reaching task**

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We investigated spatial and temporal characteristics of eye-hand coordination. Using a rapid reaching task we measured correlations of eye and hand movement latencies, taking into account the location (peripheral vs. foveal) of visual stimuli during preparation and execution of movements. Subjects repeatedly reached toward a peripheral target on a touch screen under time pressure (<550 ms) with constrained (fixated at the screen center) or unconstrained eye movements. Rewards depended on the proximity of hand endpoints to the target. The target either appeared at the same location within a block of trials ("predictable" condition) or randomly in one of two locations ("unpredictable" condition). We found that the shapes of eye and hand endpoint distributions were highly variable across subjects and conditions. Hand endpoints, but not eye endpoints, were concentrated along the line connecting the starting point and the target. The distributions of both eye and hand movement directions were symmetric (not skewed), but eye movements were systematically short of reaching the target by approximately 2.5 deg. Target predictability affected movement latencies and their relations. In the predictable condition, eye initiation latencies were longer and arrival times shorter than in the unpredictable condition. Relative latencies of eye and hand also depended on target predictability. Hand movements preceded eye movements in the predictable condition; the pattern was reversed in the unpredictable condition. Highest hand precision was attained when hand movements were initiated within 60 ms of the onset of eye movement. We conclude that target predictability determines the regime of eye-hand coordination. At high uncertainty about the upcoming visual target, early eye movements help to avoid corrective hand movements and expedite the visual feedback needed for good hand precision. At low uncertainty, subjects can afford initiating hand movement earlier and thus gain time for increasing hand precision.

26.541 **Are experience-dependent eye movements determined by implicit or explicit memory processes?**

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Eye movements during complex scene perception seem to depend on prior experience, but it remains unclear which kind of memory influences them. One study only reported experience-dependent eye movements when participants certified being consciously aware of changes in images during a subsequent recognition task, a second study produced contradictory results. An important methodological difference between these studies was that only the first included a recognition task. Thus, our study aims to clarify if experience-dependent eye movements are determined by implicit or explicit memory processes. We merged the two designs and investigated two groups of 20 participants. The first group was explicitly instructed to pay close attention during the presentation of 72 photographed scenes, whereas the second group was instructed to simply look at the scenes. For each scene there was an original and a manipulated version. Both versions were counterbalanced across participants. Further the scenes were subdivided into three blocks and three conditions: novel, repeated and manipulated. Participants saw the same eight original scenes in the first two blocks and then the manipulated version in the third block. The remaining scenes were distributed over the novel and repeated conditions. Afterwards, participants had to identify whether the photos in the third block were novel,

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repeated or manipulated scenes and to name the manipulations. When participants of the first group were aware of the manipulation, the number of fixations in the altered region was significantly higher as when they were unaware. But even then, participants made significantly more fixations to the altered region than participants who saw the same version in the first block. These results suggest that even though experience-depending eye movements for manipulated scenes reflect conscious, explicit memory it also indicates the involvement of unconscious, implicit memory independent of the awareness of the viewed scene.

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26.542 **Reading unsegmented text: The impact on fixation location and duration**

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Decisions about when and where to move the eyes are commonly assumed to be made independently (e.g., Findlay & Walker, 1999). Consequently, the influence of an experimental manipulation on fixation times in reading is typically analyzed without considering the possible impact of this manipulation on fixation locations. However, during reading, it is well-known that fixation location within the word influences fixation durations. Specifically, first-fixation duration is longer for fixations located near the center of the word than for fixations near the beginning or the end of the word. Thus, it is necessary to establish the extent to which location effects can interact with lexical variables such as word frequency, to rule out the possibility that lexical effects are at least in part due to subtle differences in fixation location. In a previous study (Reingold, Reichle, Glaholt, & Sheridan, accepted), we demonstrated that location effects on fixation duration were largely independent of the impact of word frequency (high vs. low) and parafoveal preview validity (valid vs. invalid preview). Extending this research, the present study directly manipulated a variable that was expected to influence fixation location. Specifically, we contrasted a normal text condition with a modified text condition that contained random numbers between 2 and 9 instead of spaces (e.g., John3decided8to5sell9the7table). Relative to the normal text condition, the modified text condition produced landing positions that were closer to the beginning of the word, as well as shorter saccades, longer fixations, and slower overall reading times. However, the normal and modified text conditions showed a similar pattern of word frequency and preview validity effects. The present results indicate that location effects during reading are largely independent of the influence of lexical variables, and more generally, our findings support the assumption that when and where decisions constitute independent factors in eye-movement control in reading.

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26.543 **Oculomotor Inhibition of Return in Normal and Mindless Reading**

John M. Henderson[1](jhender@mailbox.sc.edu), Steven G. Luke[1]; [1]Department of Psychology and McCausland Center for Brain Imaging, University of South Carolina

Oculomotor inhibition of return (O-IOR) is an increase in saccade latency prior to an eye movement to a recently fixated location compared to other locations. To investigate O-IOR in reading, subjects participated in two conditions while their eye movements were recorded: normal reading, and mindless reading in which words were replaced by equivalent geometric shapes. We investigated the manifestation of O-IOR in reading, and whether it is related to extracting meaning from the text or is a purely oculomotor phenomenon. The results indicated that fixation durations prior to a saccade returning to the last fixated word were longer than to other words, consistent with O-IOR. Furthermore, this effect was spatially specific: Fixation durations were longest prior to a saccade that returned the eyes to the character in the word that had previously been fixated, and dropped off as the distance between the previously fixated character and landing position increased. This result is consistent with the hypothesis that IOR is applied to the fixated character location during reading and drops off as a spatial gradient. Both of these results were found for text reading and for mindless reading, suggesting that they are consequences of oculomotor control and not of language processing. Finally, although the temporal IOR effects were robust, no spatial consequences of IOR were observed: Previously fixated words and characters were as likely to be re-fixated as new words and characters.

26.544 **The Influence of Target and Distractor Location Bias on Oculomotor Capture and Distractor Dwell Times**

John L. Jones[1](jones@psy.fsu.edu), Walter R. Boot[1], Michael P. Kaschak[1]; [1]Department of Psychology, Florida State University

When the location of a search target is more likely to appear on one side of the display, observers initiate search to that side more often and more quickly (Jones & Kaschak, in press). Moreover, the rate of initial saccades to the biased side of the display is elevated even when a clearly marked target appears on the unbiased side (Jones & Kaschak, in preparation). These results provide clear evidence that 1) participants are sensitive to and learn such biases and 2) the resulting expectations about target location compete with the visual signal for control of eye-movements. The current work explores the interaction between internal (i.e., cognitive) and external (i.e., sensory) information about likely and actual stimulus locations. We pitted target bias against abrupt distractor onsets in the oculomotor capture paradigm (Theeuwes et al., 1998). On one hand, expectations about likely target locations might buffer against capture by an abrupt onset distractor. On the other hand, if location expectations bias participants to allocate attentional resources to a specific region of a search display, this could lead to increased capture when the distractor appears in that region. We orthogonally manipulated target and distractor location bias in a task in which observers searched for a color singleton in the presence of an onset distractor. Results indicate that, in fact, both outcomes obtain depending on the bias condition and location of target and distractor on a given trial. While bias influenced the likelihood of capture, it did not modulate dwell time on the distractor when the eyes were captured. Results are not consistent with theories of capture that posit top-down modulation only with respect to dwell time after capture has occurred.

Acknowledgement: NSF grant 0842620 to MPK

26.545 **Gaze behavior of adults with Autism Spectrum Disorder does not explain change detection in dynamic scenes**

Rebecca Nako[1](beccanako@gmail.com), Antje Nuthmann[2], Teodora Gliga[1], Tim J. Smith[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]School of Philosophy, Psychology and Language Sciences, University of Edinburgh

Adults with Autism Spectrum Disorder (ASD) are known to have different patterns of visual attention compared to Neuro-typical (NT) adults in naturalistic social scenes. However, these differences are hard to reproduce in the lab using sparse/static stimuli. How do ASD adults attend to socially relevant information in dynamic scenes and what are the implications for scene perception? Attention and scene representation of dynamic naturalistic scenes was investigated between ASD and NT adults using a change blindness paradigm. Participants viewed highly cluttered videos of an actor performing a three part everyday task such as watering a plant (running water, filling watering can, watering plant). The actor always left the scene before completing the third part. Participants were asked to identify a change made to an object in the scene after the actor's exit. One of three change conditions was used: (1) an object irrelevant to the task (e.g. a cup); (2) an object touched and utilized as part of the task (e.g. watering can); or (3) an object that was implied by the task (e.g. plant). Gaze behavior and ability to detect the change was measured. The overall change detection ability of both groups was similar. However, the NT group show an increased ability to detect changes to the utilized object ($p<.05$) that the ASD group did not. Analysis of gaze behavior indicated that this difference was not due to a decrease in dwell time on the utilized object as ASD adults increased gaze to the utilized and implied objects after the action to the same degree as NT. These results suggest that both groups attend to socially relevant objects (utilized or implied) in the same way but attention to an object does not facilitate change detection to the same degree as in NT.

26.546 **Gaze Pattern Differences Between Objective and Subjective Search of E-Commerce Web Pages**

Duy Nguyen[1](ouuduy@yahoo.com), Evan Palmer[1]; [1]Department of Psychology, Wichita State University

In a classic study, Yarbus (1967) showed that an observer's eye movements varied dramatically depending on the viewing task. That study was among the first to show that high-level tasks influence eye movement patterns. Here, we seek to understand how the goals of the user affect their gaze patterns while browsing e-commerce web pages. In a pilot study, participants rated 60 still images of online shopping web pages in terms of five attribute pairs: poorly designed vs. well designed; simple vs. complex;

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bright vs. dull; masculine vs. feminine; and attractive vs. unattractive. In the current study, participants saw the 12 online shopping web pages that were rated as the most gender neutral in the pilot study and we recorded their eye movements while they performed one of three different search tasks. Participants either browsed the web page freely, performed an objective search task (e.g., find the laptop), or performed a subjective search task (e.g., find a gift for your uncle). In both of the search tasks, participants clicked an item or link to end the trial while in the free browsing task, the trial ended after 15 seconds. Consistent with Yarbus, we found differences in eye movement patterns between the three tasks, demonstrating the influence of top-down goals on gaze behavior. Gaze patterns in the free browse and subjective search tasks were similar to each other and different than the objective search task. Specifically, average saccade amplitudes were significantly larger in the objective search condition than in subjective search condition ($p < .05$) and marginally larger than in the free browse condition ($p = .068$). We have computed saliency and clutter maps for the 12 webpages in this study and are in the process of analyzing the eye movement data with respect to these dimensions.

Perception and action: Interception

Saturday, May 12, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

26.547 Independent Feature Processing in both Vision for Perception and Vision for Action

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Human vision can be divided into vision for perception and vision for action (Milner & Goodale, 1995). In vision for perception the features of an object are processed independently (Kyllingsbaek & Bundesen, 2007). Are features also processed independently in vision for action? 20 different white bars were created using 4 lengths (5-7 cm.) and 5 orientations (30°- 60°). They were presented at arms length for 40 ms. on a black computer screen one at a time on either the left or right side of a central fixation mark. A contrast adjustment procedure lowered the intensity of the bar until barely visible. Vision for perception and vision for action were evaluated in separate blocks by two types of response modes for specifying length and orientation of the bars: Symbolic specification: specifying length and orientation on a keyboard. Motoric specification: moving index and thumb to the endpoints of the bar (using about 500 ms.). Positions of the fingers were measured and specification of raw lengths and orientations calculated. The raw lengths and orientations were then categorized into 4 lengths and 5 orientations. 7 subjects completed 320 trials of both types of specifications in separate blocks. Correct/incorrect symbolic or motoric specifications of length and orientation were entered into a 2x2 chi2. This was used as a measure of independence. In all subjects the chi2 analysis of both types of specifications supported independent processing of the two features. Also, Monte Carlo simulations of specifications of the two features (based on the observed marginal probabilities of correct specification of each feature) showed no significant differences between the observed specifications and the corresponding predictions of the model assuming independent processing of features. The features of an object are processed independently in both “vision for perception” and “vision for action”.

26.548 The temporal profile of attention in a perceptual task shifts with a concurrent reach

Emma Stewart[1](emma.stewart@adelaide.edu.au), Anna Ma-Wyatt[1]; [1]School of Psychology, University of Adelaide

Attention can improve contrast discrimination at the attended location. While the dynamics of this attentional deployment have been studied with regards to saccades, the temporal profile of attention in relation to goal-directed movements is not yet fully understood. The temporal profile of attention during reaching should provide insight into how mechanisms underlying these tasks interact over time. In this study we investigated how the planning and execution of a rapid pointing movement affects the temporal profile of attentional deployment before and during a reach. Participants were presented with two discs indicating potential target locations 10° either side of a central fixation point. A central cue indicated which side the target would appear on. After a variable interval, there was a brief change in contrast at the target location. In the perceptual task, participants were asked to indicate whether they perceived an increment or decrement in contrast, and in the pointing task participants were instructed to make a reach to the cued target in addition to completing the contrast discrimination task. Eye movements were monitored throughout the task. When completing the perceptual task alone, contrast discrimination performance peaked soon after cue offset, consistent with previous findings. With the addition of a reach, contrast discrimination performance improved towards the end of the reach time. These results suggest that attentional guidance may be important for completing a goal directed movement in the last part of the reach.

26.549 The Human Homologue of Macaque Area V6A

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In monkey, the caudal part of the superior parietal lobule is occupied by extrastriate visual area V6, in the ventral part and fundus of the parieto-occipital sulcus (POs), and by visuomotor area V6A, on the anterior bank of the POs, dorsal and anterior to V6 (Galletti et al 1996). In contrast to V6, which has a retinotopic map of the contralateral visual field, V6A represents both contra- and ipsilateral visual fields and is less well retinotopically organized. The central 20°-30° of the visual field are mainly represented dorsally (V6Ad) and the periphery ventrally (V6Av), at the border with V6, and the contralateral lower visual field is over-represented in V6A, particularly in area V6Av. Both sectors of area V6A also contains arm movement-related cells, active during spatially-directed reaching movements (Gamberini et al., 2011). We previously mapped the retinotopic organization of area V6 in human (Pitzalis et al., 2006). Here, we used phase-encoded fMRI, cortical flattening, wide-filed retinotopic mapping, and fMRI responsiveness to finger pointing movements, to recognize human area V6A among the areas that surround V6. The new region borders V6 anteriorly but is distinct from it, with a clear over-representation of the contralateral lower visual field as well as of the periphery, similar to macaque area V6A. The new region shows a tendency for eccentricity to increase moving ventrally, again as in macaque V6A. Functional mapping revealed that the new region, but not V6, responds to pointing movements, as with macaque V6A. Based on similarity in position, retinotopic properties, functional organization and relationship with the neighbouring extrastriate visual areas, we suggest that new cortical region found here is the human homolog of macaque area V6A.

26.550 Attention distorts reach space

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Background: Attention improves the visual system's spatial resolution and distorts the perception of visual space: Perceived locations are repulsed away from the attentional focus (Suzuki & Cavanagh, 1997). However, little is known about whether and how attention affects visual space in action. Methods: Here, we tested the effects of exogenous attention on visually guided reach movements. Attention was drawn involuntarily to a transient, uninformative cue (white square, 72ms) at one of two locations at 11.4° eccentricity and ±45° polar angle in either the upper left or upper right quadrant, respectively. After a brief delay (56ms), a reach target (green circle, 29ms) appeared at a randomly chosen position along an imaginary half-circle within the upper visual field with the same eccentricity as the cue positions. In the ‘attended’ condition, cue and target appeared within the same quadrant, whereas in the ‘unattended’ condition they appeared in opposite hemifields. For each target location, we calculated the distance between reach endpoint and target for the attended and the unattended condition. Results & Conclusions: In the attended condition, reach endpoints toward targets in the vicinity of the attentional cue were repulsed away from the cue by up to ~0.9°, relative to the unattended condition. The spatial profile of the magnitude of this effect follows an ‘M’-shape centered on the focus of attention; i.e., the cue did not affect reaches toward targets at the cued location or far away from it. Reaction times (target onset

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to movement start) tended to be slower for targets near the cue, whereas movement times (movement start to landing time) at all locations tended to be faster in the attended than in the unattended condition. These results are consistent with an attentional distortion of visual space and suggest a parallelism between the perception and action systems for the representation of location.

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26.551 Different control modes of temporal and spatial variability in reaching movements

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Several previous studies in motor control have looked at spatial and temporal precision of arm movements under different conditions. However, none of them have focused on the benefits of giving more time to plan the movement in terms of spatial and temporal precision. With this aim we designed a task in which participants had to point towards static targets that change their saggital position trial-to-trial. Subjects could start moving once the target changed its colour (go-signal) which took place after six possible planning times of 0, 250, 500, 1000, 2000 or 5000 ms. after target onset. In a spatial condition participants were required to be precise only spatially (on a target of 0.6 cm of diameter). In a temporal condition the response time (reaction time + movement time) had to be of 800 ms. Finally, in a combined condition, they had to meet both spatial and temporal criteria. Results show that temporal precision improved with planning time in the temporal and combined condition. Spatial precision however was not affected by planning time but in addition was as good in the temporal or combined condition as in the spatial one. Finally, it took longer to start movements when there was no time to plan them (longer reaction times) and vice versa, but these differences were compensated by modulating movement times in order to meet the required time constraint of 800 ms. We suggest that temporal variability is mainly optimized by an open-loop control mode in which movements are progressively smoother and coupled with shorter reaction times as planning time increases.

Acknowledgement: This research was funded by Grant PSI2010-15867 from the Ministry of Science and Innovation of the Spanish government.

26.552 Online visual feedback of the hand suppresses gaze-dependent overshoots in memory-guided reach

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Reaching movements in the dark overshoot memorized visual targets relative to the gaze direction held just before reach onset, even if a saccade intervenes between target presentation and reach onset. The latter pattern has been cited as evidence for the updating of memorized visual target positions in a gaze-centered reference frame. However, the exact origin of the gaze-dependent overshoot is not known. Because the reach errors depend on the visual target eccentricity, all previous studies (e.g., Henriques et al. 1998; McGuire & Sabes 2009) have assumed that it reflects biases in target-related inputs to the visuomotor transformation. An alternative possibility, as of yet untested, is that the error is associated with biases in hand-related signals. Here, we tested this hypothesis through its prediction that visual feedback of the hand during the reaching movement should greatly reduce or even abolish the gaze-dependent overshoot. Six subjects sat in the dark in front of a screen behind which target and fixation LEDs were mounted 10 deg. of visual angle apart, while their eye and finger movements were recorded using EyeLink II and Optotrak, respectively. All subjects showed the typical gaze-dependent overshoot reported before (~±2 deg. at ±10 deg. retinal target eccentricity; P<0.005). The overshoot disappeared when they could see their finger during the reach (~±0.2 deg. at ±10 deg. retinal target eccentricity; P>0.37). This effect was most parsimoniously explained by a reach planning model that included biases in the transformation of proprioceptive signals into visual coordinates, for the purpose of calculating a reach vector in visual coordinates (further predictions of this model are currently under investigation). This is the first demonstration that overshoots to remembered visual targets can be suppressed entirely in healthy human subjects. This finding is consistent with our hypothesis that the overshoot arises within hand-related inputs into the visuomotor transformation.

Acknowledgement: CIHR, NSERC, Japan Society for the Promotion of Science

26.553 Hit me with your best shot: Optimal movement planning with constantly changing decision parameters.

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Humans are able to rapidly select movements that will achieve the individual's goal while avoiding negative outcomes. Trommerhäuser et al. (2003) showed that, in a rapid aiming task, people concentrated their movements around an 'optimal movement endpoint' that was modeled based on the participants' endpoint variability and the cost associated with a penalty circle that partially overlapped the target circle. Participants adjusted their endpoint when the penalty circle cost or distance between the two circles changed; however, penalty value only changed between blocks of trials. In typical daily interactions, the values associated with our movement goal vary. The purpose of the present study was to determine whether participants can adjust their endpoint when the distance between the target and penalty circles and the value of the penalty circle changed trial-to-trial. Participants aimed to a target circle in the presence of an overlapping penalty circle and received 100 points for contact with the target alone, and lost points for contact with the penalty region. In one block, the penalty circle for a given trial was either orange or red indicating that the cost was -100 or -600 points, respectively. In the other block, the penalty circle either overlapped the target circle by 9 or 13.5mm.There was a significant difference in endpoint between the two values within each distance and penalty block. However, when compared to the optimal endpoint calculated from the model, participants showed a significantly smaller shift in endpoint between the two penalty values, but an optimal shift in the distance block. We suggest participants are more optimal with a random changing of distance because the distance between the two circles is an intrinsic property of the visual stimuli, whereas the color associated with each the penalty value requires additional cognitive resources to interpret and predict the potential costs.

Acknowledgement: NSERC

26.554 Effects of visual induction on egocentric perception and manual behavior are short-lived

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A pitched visual inducer in the retinal periphery produces illusory changes in the perceived elevation of a small luminous target on a dark field. The inducer also affects manual behavior when subjects point at the target with the unseen hand. This manual effect depends on hand-to-body distance: When the arm is fully extended, pointing is veridical; when the arm is close to the body, gross pointing errors occur, similar to the errors in visual perception (Li & Matin, 2005; Li, E. Matin, Bertz, & L. Matin, 2008). In the present Experiment 1, subjects pointed at an eye-level target. In Experiment 2 they pointed horizontally at eye level (no visual target). In both experiments, we measured the manual behavior as a function of hand-to-body distance during the presence of the inducer and for 10 minutes after inducer offset. In both cases the hand-to-body distance effect disappeared shortly after inducer offset. We suggest that the rapid disappearance of the distance effect is a manifestation of processes in the dorsal visual stream that are involved in updating short-lived representations of the body in egocentric perception and manual behavior.

Acknowledgement: Supported by NSF Grant BCS-06-16654.

26.555 Temporal dependency in estimation of target velocity disappears in self-generated stimuli

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Motivation: It has long been reported that perceptual estimation of stimulus is biased toward the immediately preceding stimulus (Holland & Lockhead, 1968), and we have recently shown that the bias is modulated by the temporal correlation of stimuli history (Kwon and Knill, VSS 2011). Here, we asked whether the temporal dependency in perceptual estimation can be modulated by the observers' prior knowledge on how the stimuli velocities are generated. Method: We used a motion extrapolation task in which a target moved and disappeared behind an occluder and subjects had to hit the target when it was supposed to be in the designated hitting zone. In the first condition, subjects actively generated the velocity of target (active condition) by hitting the virtual target with a pusher. The target launched when the pusher contacted target at the speed of the pusher. The same group of subjects participated in the second condition. In the second condition, the stimuli velocity was passively presented, but the sequence of stimuli velocities was what the same subjects generated in the first condition (active-passive condition). In the third condition, a new group of subjects participated. The sequence of stimuli velocities was the same as the other conditions (passive condition). Results: The bias toward the immediately preceding velocity was close to zero in the active and the active-passive conditions, whereas the bias was significantly different from zero in the passive condition. On the contrary, the bias toward the mean velocity was comparable in all three conditions. Conclusions: Temporal dependency in estimation of velocity disappears when subjects actively generated stimuli. Surprisingly, the same effect was observed when the stimuli were presented passively, if subjects know that the sequence of stimuli generated by themselves. Perceptual estimation of stimulus velocity is modulated by subjects' prior knowledge on how the stimuli are generated.

Saturday PM

26.556 **Hand-specificity in gaze-dependent memory-guided reach errors**

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Reaching movements toward remembered visual targets in a dark environment show overshoot effect relative to the gaze direction, but the exact origin of this overshoot is unknown. Because the reach errors depend on the visual target eccentricity, all previous studies (e.g., Henriques et al. 1998; McGuire & Sabes 2009) have assumed that it reflects biases in target-related inputs to the visuomotor transformation. This possibility predicts the error pattern is hand-independent. So far, however, it has only been studied for the right hand. Here, we directly compared left and right arm reaching movements toward remembered visual targets in the dark. Right-handed subjects sat in front of a screen behind which five bicolor LEDs were attached at 0, ±10, and ±20 deg. of visual angle in a completely dark room. While fixating in the direction of a previously shown fixation LED, a red LED appeared to signal the reach target. After a memory delay of 1000 ms subjects started reaching to the remembered target position as accurately as possible (i.e., without any time pressure). They executed reaching movements with their left and right index finger alternately. Eye and hand movements were recorded using EyeLink II and Optotrak, respectively. Results so far showed gaze-dependent overshoots for both hands ($P<.005$). Interestingly, the effect of target eccentricity interacted with hand ($P<.005$), which appeared to reflect a relatively stronger overshoot effect for the left hand in the right visual field. This finding shows that the overshoot does not only reflect biases in target-related, but also in hand-related inputs to the visuomotor transformation. This has implications for studies of reaching movements towards proprioceptive targets defined by the non-reaching hand.

Acknowledgement: Japan Society for the Promotion of Science, CIHR, NSERC

26.557 **Terminal, but not concurrent, prism exposure produces perceptual aftereffects in healthy young adults.**

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A short period of prism adaptation (PA) has been shown to reduce neglect symptoms, but evidence suggests this effect might be restricted to visually guided actions, leaving perception unaffected. One explanation for this dissociation potentially lies in the method used to promote adaptation. The majority of studies have used concurrent exposure, a technique that promotes a change in felt arm position (proprioceptive straight ahead, PSA). Few studies have used terminal exposure, a technique that promotes a shift in perceived visual straight ahead (VSA). Thus, the observed positive effects of PA may appear to be primarily action based because studies have adopted an exposure procedure that promotes a change in felt arm position. Here we compare the effects of the two exposure types on a perceptual and a manual line bisection task in healthy young adults. Before and after six minutes of exposure to leftward displacing prisms we took two measures of perceived straight ahead (PSA and VSA) and administered two line bisection tasks (a manual task and a perceptual landmark task). During the exposure period participants made pointing movements while the view of their pointing arm was either (i) restricted to the final part of the pointing movement (terminal exposure) or (ii) restricted to the second half of the pointing movement (concurrent exposure). In line with previous research, terminal exposure produced a larger shift in VSA; concurrent exposure produced a larger shift in PSA. Change in manual bisection from pre to post exposure was found to be significantly greater after concurrent exposure. In contrast, a shift in performance on the perceptual landmark task was found only after terminal exposure. Taken together, our results shed light on the underlying mechanisms of prism-induced neglect recovery, demonstrating that task performance depends on the type of PA.

Acknowledgement: Heart and Stroke Foundation Centre for Stroke Recovery

26.558 **The same object and at least three different grip apertures**

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It is known that people perform different grip apertures when required to reach and grasp objects or when required to manually estimate them. Typically, larger spans between index and thumb fingers are found during grasping then during manual estimation (Foster, Fantoni, Caudek & Domini, 2011). An important difference between these tasks concerns the position of the hand with respect to the object. This hand position signal might provide additional information used for the shaping of the grasp (e.g., egocentric distance for visual information scaling). Participants were asked to grasp a virtual object without seeing their hand and without haptic feedback. This grasp was measured in three tasks: (a) in a reach-to-grasp task; (b) in a grasp-on-location task, in which the hand was positioned by a robotic arm in the locations participants reached in the reach-to-grasp task; (c) in a grasp-off-location task, in which the hand was located away from the object and close to the body. The disparity-defined virtual object was composed of three vertical rods: one rod was positioned midway and in front of two flanking rods. Four depth separations were used between the central rod and the flanker rods, and this arrangement of rods was presented at two distances with consistent vergence and accommodative cues. We found that the final grip aperture was consistently larger in the grasp-on-location than in the grasp-off-location task. The exact same visual information thus gave rise to different grasping behaviors depending on the hand's position with respect to the object. However, an even larger final grip aperture was observed in the reach-to-grasp task, even though hand's positions were coincident with those used in the grasp-on-location task. Actively generated movements towards the same objects thus produced yet a different grasping behavior.

26.559 **Flexible adaptation of hand orientation to changes of object orientation during grasping**

Owino Eloka[1](owino.eloka@uni-hamburg.de), Volker H. Franz[1]; [1]General Psychology, University of Hamburg

In grasping the orientation of an object plays a significant role, as it influences both the „grasping component" as well as the „transport component " (Jeannerod, 1981, 1984). Therefore investigating the effects of changing object orientation during the movement might provide further insights to the visuomotor control of grasping. To this end, 20 participants grasped a vertically aligned bar (length = 50 mm, width = 20 mm) with a precision grip. Participants could freely choose a comfortable grasp axis. In 20 % of the trials the orientation of the bar was changed during the movement (by 20° or 90°). The change occurred after index finger or thumb moved 2 cm away from the starting position, or after 2/3 of the movement distance was covered. In the remaining 80 % of the trials the orientation of the bar was not changed. When the orientation of the bar was not changed, participants grasped it along its length. When the bar was rotated by 20°, participants also changed their hand orientation, and kept grasping the bar along its length. Also, in both conditions the maximum grip aperture was scaled to the length of the bar. However, when the bar was rotated by 90° participants grasped the bar along its width, scaling the MGA to the width of the bar, but not altering the orientation of their hand. Interestingly these adaptation processes did not depend on the moment of perturbation. Our results indicate that the visuomotor system is able to process information about object orientation flexibly at different stages of the movement, depending on external demands (orientation of the object) and internal factors (comfort of the grip).

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Sunday Morning Talks

Perceptual organization

Sunday, May 13, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 1-3

Moderator: Mary Peterson

31.11, *8:00 am*

Emergent Features Predict Grouping in Search and Classification Tasks

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Emergent Features (EFs) are properties that are not possessed by any individual part, but arise only from the configuration of parts. They are furthermore processed more quickly than are the properties of the parts, and the presence of EFs makes configurations more salient than their parts. Converging evidence from two tasks showed strong support for EFs as the basis for grouping. In the Search Task, discrimination between the orientations of line segments (bases) was facilitated by the addition of "context" line segments, but only when those contexts created EF differences between the target shape and the shape of the distractors. Faster search times in the "composite condition" relative to the base (i.e., no context added) indicate the presence of a Configural Superiority Effect (CSE; Pomerantz & Portillo, 2011). In the Classification Task, either the base or the context was relevant for classifying composite images into predetermined response categories. Variation in the irrelevant portion of the image slowed performance relative to a control condition where the irrelevant portion does not vary from trial to trial. Such a detriment in performance is termed Garner Interference (GI; Pomerantz & Garner, 1973), and is indicative of subjects' reduced ability or preference to pay selective attention, electing instead to pay more attention to the whole configuration. We reasoned that when elements are perceptually organized, forming a Gestalt, (1) discrimination is enhanced when contexts produce more salient properties (yielded a CSE), and (2) the ability to selectively attend to any one element is impaired (GI). Thus, CSE and GI effects can be diagnostic of grouping. Results indicated that the type and number of EF differences and similarities, coded by using the Tversky Contrast Model (Tversky, 1977), can successfully predict both of these effects and, by extension, grouping.

31.12, *8:15 am*

P[A and B] > P[A]P[B] for independent events A,B: erroneous use of probability in a simple visual task

James Tee[1](james.tee@gmail.com), Hang Zhang[1], Laurence T. Maloney[1]; [1]Department of Psychology, New York University

Statistical models of optimal visuo-motor performance presuppose that visual processing of probability information conforms to standard probability theory (Maloney & Zhang, VisRes, 2010). We test whether observers combine the visually-estimated probabilities of two independent events normatively. Task: During each trial, a subject chose between a single roulette wheel with probability r of success and a pair of independent roulette wheels with probabilities p and q of success. The observer's estimates of p, q, and r were based on visual judgments of the fraction of each roulette wheel colored gold. The wheels were spun and the observer won a small monetary prize (i) if he chose the single wheel and it stopped in the gold, or (ii) chose the pair and both stopped in the gold. We used a staircase procedure to estimate the r for which the subject chose the pair as often as the single wheel: r~(p,q). Conditions: Twelve experiment conditions corresponded to twelve choices of (p,q), with p being greater than or equal to q. They included four homogeneous groups of conditions of three pairs each, where p1q1 = p2q2 = p3q3. Ten naïve subjects participated. Results: We tested whether observers' indifference points satisfied r = pq, implying the observer was combining probabilities normatively. All observers had r > pq (Bonferroni-corrected t-tests): they overestimated the conjunction probability. We next tested whether observers assigned the same (erroneous) probability to each of the three pairs in a homogeneous group: did they converge on the same r for each of p1q1 = p2q2 = p3q3? 9/10 observers passed this test of homogeneity. Conclusions: Observers' combination of probabilities in a simple visual task showed systematic deviations from normative theory.

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31.13, *8:30 am*

Invariance of Correlation Perception

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Previous work has shown that the perception of correlation in scatterplots can be characterized by two simple laws: a linear Fechner-like law for precision and a logarithmic Weber-like law for accuracy (Rensink & Baldridge, 2010). It also appears to be rapid, being largely complete within 100 ms of presentation (Rensink, 2011). This suggests that although correlation may be conveyed by a complex carrier, it nevertheless is−or at least, is based on−a relatively simple property. To investigate the nature of the process involved, two sets of experiments tested whether different kinds of visual design influence correlation perception. The first set involved scatterplots with various styles of dot (or symbol). Precision was determined via the just noticeable difference in correlation for two side-by-side scatterplots. Accuracy was determined by direct estimation, using reference scatterplots having fixed upper and lower values, and a test scatterplot adjusted to have its apparent correlation be midway between them. The second set used similar methodology but a different carrier, with the vertical position carrying the second data dimension being replaced by a simple feature such as size. Such 'augmented stripplots' then conveyed correlation via the relation between horizontal position and size. Twelve observers were tested in each condition. Results showed a surprising degree of invariance for scatterplot symbol: different sizes, colors, and even shapes had little effect on precision or accuracy. This suggests that only the centers of the symbols are relevant, ruling out the involvement of simple operations such as blurring. In addition, there was also an interesting degree of invariance for carrier: accuracy and precision in augmented stripplots obeyed linear-logarithmic laws similar to those for scatterplots. These invariances suggest that correlation perception may be a general process that is both rapid and sophisticated.

Acknowledgement: Supported by the Natural Sciences and Engineering Research Council of Canada, and The Boeing Co.

31.14, *8:45 am*

Feedback from Domain-Specific Visual Recognition Processes: Evidence from Selective Digit Metamorphopsia

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RFS, a 61-year-old geologist with cortical atrophy that may reflect early-stage cortico-basal degeneration, is selectively impaired in perceiving and comprehending the Arabic digits 2-9. Presented with a digit in this range, he reports seeing an uninterpretable jumble of contours ("like spaghetti"), and is unable to identify, copy, or even trace the digit. In contrast RFS is intact in processing the digits 0 and 1. Furthermore, he accurately perceives and comprehends number words (e.g., seven) and Roman numerals, and his mathematical skills are excellent when tested without Arabic numerals. Processing is also intact for most letters and other symbols (e.g., #), although RFS reports mild perceptual distortion for a subset of letters (M, N, R, S, Z). Remarkably, the digits 2-9 are not only misperceived, but also distort RFS's perception of other visual stimuli in the spatial or temporal vicinity. For example, RFS was entirely unable to identify pictures enclosed within, or overlaid by, digits in the 2-9 range, but was 100% correct when the enclosing or overlaying characters were 0s, 1s, or letters. The digits 2-9 also impaired identification of subsequent stimuli. A pre-mask of digits or # symbols was presented for 2 s, followed after a variable ISI by a target letter. RFS was severely impaired in identifying the letter at ISIs of 1 s or less, but only when the pre-mask consisted of digits in the 2-9 range. We interpret RFS's impairment in terms of feedback from domain-specific recognition processes. We propose that in RFS a malfunctioning digit-recognition process not only fails to identify digits in the range 2-9, but also

Sunday AM

See page 3 for Abstract Numbering System

sends disordered--and disruptive--feedback to earlier perceptual levels of representation. Finally, we suggest that phenomena from other domains can be explained in similar terms (e.g., selective prosopometamorphopsias in which faces appear flattened, melted, or otherwise distorted).

31.15, *9:00 am*

Increases in alpha-band electrocorticographic oscillations and decreases in fMRI signals reflect surround suppression in V1 but not extra-striate cortex

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Introduction: Electrical brain signals are typically decomposed into different frequency bands thought to represent different functions. In particular, 8-12Hz (alpha) oscillations are debated to reflect functionally important processing, or simply idling. Electrocorticography (ECoG) measures electrical activity directly in humans using subdural electrodes. Here, we model population receptive field (pRF) properties using both fMRI and ECoG in the same subject. A recent extension of the pRF modeling approach reconstructs a center-surround profile, driven by increases and decreases in fMRI amplitudes in V1. We link different frequency bands to fMRI signals and the underlying neural population's properties. Methods: We used stimuli consisting of contrast-defined bar-sweeps though the visual field intermixed with mean-luminance blocks (baseline). We determined the pRF properties and visual area layout using 7T fMRI (Dumoulin and Wandell, 2008). Subdural ECoG electrodes were then implanted in the same subject and the same stimuli were shown. ECoG data was filtered into different frequency bands, which were analyzed separately using the same methods. Results: Using ECoG, 30-120 Hz oscillations (gamma) allowed pRF modeling in V1 and IPS but without a center-surround configuration. Different response profiles were observed in V1 and IPS visual field maps in alpha oscillations. In contrast to surrounding frequencies, alpha increased when the contrast-defined bar was in the surround of the V1 pRFs. This increase in alpha-oscillations corresponds to the decrease in response below the baseline using fMRI. In IPS no center-surround configuration was found in either fMRI or ECoG data. Unlike V1, alpha oscillations increased during mean-luminance blocks. Conclusions: Both fMRI and ECoG recordings produce comparable estimates of the pRF. The fMRI signal cannot be explained by one ECoG frequency band alone. The same frequency band can reflect different functional processing depending on cortical location. Alpha oscillations reflect inhibitory signals in V1 and resting-state in extrastriate cortex.

31.16, *9:15 am*

Stimulus predictability affects early sensory components of the ERP response

Sung Jun Joo[1](sjjoo@uw.edu), Geoffrey M. Boynton[1], Scott O. Murray[1]; [1]Department of Psychology, University of Washington

Predictive coding models suggest that neural responses in early visual areas can be reduced if incoming sensory input matches feedback from top-down predictions. If such feedback processes are occurring, then specific hypotheses can be made about their expected time-course and dependence upon stimulus timing. In particular, if surrounding flanking stimuli precede the onset of a target by a sufficient length of time, then the feedback process is likely to be in place and stabilized before the onset of the target. Thus, differences in flanking configurations that affect target predictability should appear early in the neural response to the target. To test this, we measured event-related potentials (ERPs) to the onset of a briefly flashed (100 ms) oriented target. Target predictability was manipulated by changing the relative orientation of flanking stimuli. The flankers were presented 1~2 s before the target to ensure that any predictive, feedback process was in place before target onset. In Experiment 1, we found that the orientation relationship in a three element configuration (one target and two flankers) influenced early ERP responses (~150 ms) at electrode sites near the occipital pole (Oz, O1, O2, POz, PO3, and PO4). ERPs to targets that matched the flankers had lower amplitudes than targets that did not match the flankers. In Experiment 2, we measured ERPs to targets in three five-element conditions: same (VVVVV/HHHHH), orthogonal (HHVHH/VVHVV), and alternating (VHVHV/HVHVH). Importantly, the orientation relationship between the target and immediately adjacent flankers remains the same in the orthogonal and alternating conditions (e.g., HVH/VHV); only the orientation of the most distant flankers is changed. The early component of the ERPs showed lower amplitude in the same and alternating conditions (predictable target) compared to the orthogonal condition (unpredictable target). These results suggest that stimulus predictability can influence initial feedforward stimulus processing.

31.17, *9:30 am*

The neural correlates of spatiotemporal form integration in object and motion perception

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The perception of a moving object depends on the neural integration of form and motion information over space and time. Form and motion perception have historically been considered independent processes; however, research demonstrates that these processes interact in various and complex ways. Spatiotemporal form integration describes the process by which the visual system is able to integrate information about the shape of an object over space and time to form percepts that can mutually support both form and motion perception. A revealing example of this is the perception of static illusory figures generated by sequentially presented inducers. Here, we demonstrate that this type of spatiotemporal form integration can also lead to percepts of moving figures. This motion percept arises in the absence of any correlated motion energy in the image. We use fMRI to identify the neural correlates of spatiotemporal form integration in the context of object and motion perception. In a block design, inducers were flashed sequentially in each block to generate one of four experimental conditions: a static or moving illusory square percept, or a static or moving percept with no illusory square. Univariate GLM analyses of BOLD signals reveal that V3, V3AB, V4v and LOC preferentially respond when an illusory figure is present independently of whether or not it is moving. Additionally, visual areas hMT+ and KO show selective processing of the moving figure. Multivariate pattern analyses support these findings and also reveal that spatiotemporal form integration operates in a hierarchical fashion across visual areas. We conclude that the visual system can retain and update local and global form information over space and time leading to percepts of stationary, as well as moving objects. Furthermore, spatiotemporal form integration is mediated at least in part by mechanisms within specific regions of retinotopically organized visual cortex.

Eye movements: Remapping

Sunday, May 13, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 4-5

Moderator: Michele Rucci

31.21, *8:00 am*

The cost of making saccades

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A considerable body of evidence indicates that, after every saccade, spatial representations are updated on the basis of a copy of the saccade command. Since this corollary discharge may not match perfectly the actual saccade, this operation presumably comes at a cost. Here, we report results obtained with a novel gaze-contingent display procedure, developed to measure the average error introduced by each saccade, overcoming several limitations of previous studies. Observers were instructed to search for two hidden targets in complete darkness. They were told that the two targets would appear as soon as they looked straight at them. In realty, the targets were briefly displayed at the current gaze position after a predetermined number of saccades. Two conditions were examined: in the first (visual localization), at the end of the trial subjects adjusted the position of two cursors on the screen to match the remembered locations of the two targets. In the second condition (saccadic localization), subjects saccaded back to the remembered position of the first target at the end of the trial. In the absence of visual references, this task can only be performed on the basis of extraretinal knowledge of eye position. We show that subjects were able to reliably localize the two targets even after multiple saccades. However, every saccade increased the radius of the localization region by approximately 20′, suggesting that this is the intrinsic error associated with corollary discharge. This loss of accuracy did not occur when visual references were present: a single 5′ dot displayed throughout the trial at the center of the monitor maintained performance constant irrespective of the number of saccades. That very similar results were obtained in the two conditions of visual and saccadic localization suggests that common spatial representations are used for both tasks.

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31.22, *8:15 am*

Task-relevant remapping of peripheral information at the time of saccades.

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In the temporal proximity of a saccade, visual attention can be predictively remapped, anticipating future retinal locations of the stimulus (Rolfs et al, 2011). Here we show that the perceptual strategies associated with pre-saccadic processing are not just related to the retinal location of the stimulus, but also take into account the spatial layout of pre- and post-saccadic information. We used a classification image paradigm and a stimulus layout in which eccentricity matched locations had different valences for the task of detecting a perisaccadic signal. In a yes/no task, observers detected a bright Gaussian blob presented for 30 ms that was embedded in white noise. The blobs were presented at different times relative to saccadic onset in one of six spatial locations. On each trial, the saccadic direction was randomly cued (North, East, South, West) and a homogeneous allocation of spatial attention across the six locations was ensured by randomizing the location tested (with post-stimulus response cue). We estimated perceptual templates for each location tested for pre-saccadic (-200 to -60 ms from saccadic onset), peri-saccadic, (-60 to 0 ms) or post-saccadic stimuli (0 to 100 ms). Around the time of the saccade, templates were weighted with a specific temporal dynamic, revealing predictive remapping in peri-saccadic conditions by showing facilitation for both the future possible retinal locations of the target and other extra-foveal locations outside of the saccadic trajectory. Critically, the templates revealed different weighting for two eccentricity matched locations based on whether they were processed by retinal locations that would fall in a possible target location after the saccade or not. This suggests that predictive remapping might be a general mechanism not only for retinal locations associated with destinations of future saccades but also at extrafoveal locations that will fall (after the saccade) in possible future target locations.

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31.23, *8:30 am*

Allocation of attention across saccades

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Whenever the eyes move, spatial attention must keep track of the locations of attended targets as they shift on the retina. We report the first direct evidence for transsaccadic updating of visual attention to cued targets. While observers prepared a saccade, we flashed a salient cue in their visual periphery and measured the allocation of spatial attention before and after the saccade using a tilt discrimination task. Across the saccade, attention was sustained at the cue's location in the world, despite the cue's large shift on the retina; attention at the retinal location of the cue decayed quickly after the eye movement. Moreover, just before the saccade, attention was allocated to the cue's future retinal location, its remapped location. This behavioral result supports the physiological evidence for the predictive activation of some neurons seen when an attended stimulus will fall in their receptive field after a saccade.

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31.24, *8:45 am*

Remapping of attentional priority across the entire visual field

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During natural vision, the positions of stationary objects change on the retina with each eye movement. However, our perception of the visual scene remains stable. It is thought that this stability arises, at least in part, by the visual system's ability to update spatial information. It has been previously shown that neurons in the lateral intraparietal area (LIP) predictively respond to the presence of objects in their future receptive fields around the time of a saccade (Duhamel et al., 1992). However, it is unknown whether this remapping contains information about the priority of the objects or just about their location in space. Further, it is not known whether information about all objects is remapped or whether only information about an attended object is remapped. To investigate this, two animals were trained to perform a task in which they searched for a reward-loaded target among 10 objects consisting of targets and distractors. After the stimuli appeared, the subjects were free to move their eyes to find the reward-loaded target. Stimuli were spaced such that when looking at one stimulus, another was in the LIP neuron's receptive field. Responses of LIP neurons were significantly higher to targets compared to distracters. During fixation, the latency of this significant difference was at least 70 ms. When brought into the receptive field by a saccade, the latency of this difference appeared as quickly as 20 ms, showing a predictive remapping of stimulus priority. This short latency difference appeared across the entire visual field and was independent of eye movement direction and location. We suggest that the attentional priority across the entire visual field starts to be transferred to the future receptive field of neurons just before the initiation of the saccade and is significantly distinguishable shortly after the end of the saccade.

Acknowledgement: NIH Grant EY019273, The McKnight Foundation

31.25, *9:00 am*

Effects of motion-induced perceptual mislocalizations on saccade landing position

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Psychophysical studies of spatial localization have demonstrated that motion can influence the perceived location of a stationary stimulus. For example, drifting sinusoidal gratings within a static Gaussian envelope produce systematic errors in perceptual localization such that the envelope appears shifted in the direction of motion (De Valois & De Valois, 1991; Ramachandran & Anstis, 1990). However, the relationship between errors in the perceptual and visuomotor systems is poorly understood. In a series of experiments, we examined whether illusory position shifts induced by drifting Gabors could influence saccade landing position. Subjects were presented with Gabor targets that could appear at random locations in the left or the right visual field and drifted either rightward or leftward. Subjects made reactive saccades to the Gabor following its onset. Subjects' saccade landing positions were biased in the direction of the Gabor's drift, and this effect was present with stimulus durations as short as 60 ms. The effect persisted for volitional saccades in which subjects were cued to saccade to the Gabor following a variable delay. Comparison with a control condition in which subjects were presented with drifting gratings within a hard aperture demonstrated that this effect was based on a shift in perceived location, rather than induced by motion signals alone. Finally, we provide evidence for saccadic adaptation based on error signals from the perceived (illusory), rather than physical, location of the target. We induced saccadic adaptation by presenting a static Gabor target on each trial and replacing it with an inward drifting Gabor upon the initiation of the saccade. This resulted in a decrease in saccade amplitude over the course of 200 trials. Together, our results provide evidence for a rapid, adaptive mechanism by which the visual system updates moving target positions to improve the accuracy of saccadic eye movements to moving objects.

31.26, *9:15 am*

Retinotopic Interference: Systematic misperception of colors after a saccade

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Our visual world feels stable, but with each eye movement, the retinotopic (eye-centered) locations of objects change dramatically. Increasing evidence suggests that spatial representations are coded retinotopically (Golomb et al, 2008 J.Neurosci.), even at higher stages of processing (Golomb & Kanwisher, in press Cerebral Cortex). What does this mean for the perception of object features? Here we report a systematic distortion of color perception occurring immediately after a saccade. Subjects viewed an array of colored stimuli and clicked on a colorwheel to report the color of the "cued" stimulus. The cue was always presented before an intervening saccade, and the task was to report the color at the spatiotopic (world-centered) location of the cue. However, if a differently colored distractor was present at the retinotopic location, the distribution of responses was shifted in color space toward that retinotopic color. This "feature mixing" was spatially specific, driven by the color of a distractor in the retinotopic – but not an equidistant control – location. Fitting the data with probabilistic models revealed that in addition to errors caused by random guessing and accidentally misreporting the wrong color, a significant shift in color space remained, as if the retinotopic distractor color were blending with the true color perceived at the spatiotopic location. These findings indicate that perceptual distortions around the time of a saccade are not limited to spatial or temporal judgments (Ross et al, 1997 Nature), but also include erroneous mixing of feature information from the wrong location. Importantly, however, we found no feature mixing in a retinotopic task: retinotopic colors were reported veridically, with no interference from spatiotopic distractors. Thus, our apparently spatiotopic behavior is based on underlying retinotopic representations that must be updated with each saccade, and this updating is imperfect, producing systematic color misperceptions even after spatial pointers have been updated.

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31.27, *9:30 am*

Predictive remapping preserves elementary visual features across saccades

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Immediately prior to an eye movement, spatial information about potentially relevant visual objects is updated to compensate for the retinal displacement caused by the saccade. Although much is known about the processes involved in such updating, it remains unclear whether predictive remapping preserves an object's visual features across saccades. To investigate whether featural information of a probe object is updated during predictive remapping, we used a visual crowding paradigm. Observers executed a saccade to identify a probe letter presented at a known location in the periphery and at various intervals prior to the saccade. Flankers presented in the opposite visual field to the probe, but at screen positions that flanked the predicted post-saccadic location of the probe (the probe's "remapped location") reduced observers' ability to report the identity of the probe. This decrease was greater when probes and flankers shared elementary visual features compared with probes and flankers that were featurally distinct. Furthermore, probe identification was poorer when flankers appeared within the critical distance (half the eccentricity) of the probe's remapped location, than when flankers appeared beyond this distance. Finally, the pre-saccadic time course of this "remapped crowding" effect closely matched the neurophysiological time course of activity in neurons that predictively remap spatial information, previously reported in single-cell studies. Our findings reveal a form of non-retinotopic crowding, in which visual features from different visual fields are integrated due to predictive remapping. Remapped crowding is consistent with the notion that predictive remapping not only updates location information, but also preserves an object's featural information across saccades.

Acknowledgement: Australian Research Council

Binocular vision

Sunday, May 13, 10:45 - 12:30 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Ben Backus

32.11, *10:45 am*

The Functional Advantage of Slit Pupils

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There have been three hypotheses about the utility of slit pupils: 1) Larger adjustments in area with simple musculature; 2) better image quality for contours perpendicular to the pupil's long axis; 3) preserves chromatic-aberration correction in some lenses when pupil is constricted. These hypotheses do not explain why slits are always vertical or horizontal relative to the upright head, nor why they are vertical in terrestrial predators (e.g., domestic cats) and horizontal in terrestrial grazers (horses). Humans use blur to estimate depth in front of and behind fixation where depth from disparity is imprecise (Held et al., 2011). We simulated retinal images with various pupils to determine depth-of-field blur for different kinds of natural scenes. This leads to a new hypothesis concerning slit pupils. With slit pupils, depth of field is astigmatic: shorter for contours orthogonal to the pupil's long axis; longer for perpendicular contours. Thus, depth from blur is more precise for orthogonal contours. The ground is a common environmental feature for terrestrial predators and grazers. With the head upright, the ground is foreshortened vertically in the retinal image, increasing the prevalence of horizontal contours. Vertical slits of terrestrial predators align the orientation of the shorter depth of field with horizontal contours allowing these animals to make finer depth discriminations along the ground, an advantage in their niche. Eyes of terrestrial grazers are laterally positioned in the head, so when the head pitches downward to graze, the pupils are roughly vertical relative to the ground. Again this aligns the orientation of the shorter depth of field with horizontal contours along the ground, which is advantageous (at least while grazing). We hypothesize that the orientation of slit pupils is an adaptation that provides some animals advantageous depth discrimination relative to common contours in their environment.

Acknowledgement: NIH

32.12, *11:00 am*

Explaining stereopsis in the absence of binocular disparities

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'Stereopsis' refers to the vivid impression of solid form and immersive space obtained under binocular viewing of real scenes. Evidence suggests that this perceptual phenomenon is not simply a product of binocular mechanisms. Visual characteristics associated with stereopsis are reliably reported by naïve observers under monocular-aperture viewing of pictorial images (Vishwanath & Hibbard, 2010). One explanation for this effect is the difference in depth-cue coherence between binocular and monocular-aperture viewing of pictures. In the former, disparity and vergence cues conflict with pictorial depth, while in the latter, these conflicting cues are eliminated, putatively causing the impression of stereopsis and a greater perception of depth relief (e.g., Ames, 1925; Michotte, 1948). Results: Subjects rated depth impression in photographs of real scenes for different cue-conflict conditions. Surprisingly, removal of conflicting binocular cues alone had the smallest effect on depth impression, while large effects were reported between conditions where there was no change in conflicting binocular cues. Subjects also judged magnitude of curvature-in-depth for images of random-textured elliptically curved surfaces. Again, contrary to the cue-conflict account, there was no effect of viewing condition (Binocular-vs.-Monocular-Aperture) on perceived curvature despite significant main effects of underlying curvature and tilt. Importantly, variance of curvature settings was lower for Monocular-Aperture viewing. Furthermore, we find that the impression of stereopsis can be elicited by solely manipulating distance cues (depth-of-field blur and focus distance) without explicit changes to depth-cue conflict. Congenital strabismics also report an impression of stereopsis under monocular-aperture viewing. These results are inconsistent with the standard view that the impression of stereopsis is a by-product of binocular vision or retinal parallax, or, that it is simply associated with changes in the magnitude of perceived of depth relief resulting from changes in depth cue coherence/conflict. The results are, however, consistent with the theory that stereopsis is a perceptual attribute related to the reliability of visual estimates of scaled (absolute) depth.

32.13, *11:15 am*

No role for early stereo in scene recognition

matteo valsecchi[1](matteo.valsecchi@gmail.com), Baptiste Caziot[2], Benjamin T. Backus[2], Karl R. Gegenfurtner[1]; [1]Allgemeine Psychologie Abteilung, Justus-Liebig Universität Giessen, [2]Graduate Center for Vision Research, SUNY College of Optometry / SUNY Eye Institute

Binocular disparity, like brightness and chromaticity, is invariably present in the scenes we encounter in our daily life. Yet, whether and how early stereo contributes to the visual processing of natural scenes is largely unknown. In a first experiment we presented observers with images of forests in 2D or 3D for 17 to 100 ms, followed by a (2D or 3D, respectively) mask. A 2AFC match to sample task followed. Disparity did not increase recognition performance for any presentation time. Similar results were found in a second study that used artificial grayscale scenes that consisted of several dozen randomly oriented cubes suspended in space. One explanation could be that disparity extraction is slow. To test this explanation we ran a third experiment using simple scenes created by Random Dot Stereograms with added luminance cues. In each scene, 8 noncentral locations contained patches defined by disparity and luminance contrast relative to the background. The task was again 2AFC match to sample, with distracters having a different configuration. Stereo coherence and contrast were titrated to provide 75% accuracy with 120 ms presentation. Reducing presentation time affected contrast and stereo pattern recognition similarly, and both patterns were still recognized above chance at 67 ms, suggesting that stereo extraction was not slow. Finally, we used a 2AFC in which one choice matched the contrast configuration and the "distracter" matched the disparity configuration. Participants gave some weight to stereo, but they chose the contrast pattern with higher probability than predicted based on relative visibility. In sum, our results show that stereo was available, but it was not used for fast recognition of the natural and artificial scenes we used. Instead, participants relied on features defined by other cues, such as luminance and color.

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32.14, *11:30 am*

Stereoscopic Latency

Baptiste Caziot[1](bcaziot@sunyopt.edu), Matteo Valsecchi[2], Karl Gegenfurtner[2], Benjamin Backus[1]; [1]SUNY State College of Optometry, [2]Giessen University

In the laboratory stereoscopic perception is often slow, and perhaps for this reason its contribution to early visual processing has been neglected. It has long been known that stereoscopic depth can be perceived in briefly presented displays, but early work did not employ masking procedures or measure response times, and thus could not address how quickly disparity signals become available. We conducted experiments in which the task was to choose which side of a stereo LCD display contained a disk with 5 arcmin crossed disparity relative to background and fixation (dense RDS, disk diameter 2 deg, eccentricity 5 deg). The other location had a disk with 5 arcmin vertical disparity. The disks were displayed for 17, 34, 50, or 67 ms, and were followed immediately by a mask that remained until response. The disks were presented against a zero-disparity background. The mask was flat with 0 or 5 arcmin disparity, or had two disks in crossed or uncrossed disparity, or was binocularly uncorrelated. Accuracy was above chance at 17 ms for some conditions and increased with display duration. Accuracy was similar in most conditions; it improved when no mask was used. Accuracy was degraded when relative disparity was impoverished by removing the background. Accuracy was at chance for the crossed-disks mask. Mean response times were 300-400 ms; RT was lower (with accuracy still above chance) when the task was speeded. We conclude that relative disparity is made available quickly, while the process of constructing perceived depth has a long integration window. We measured this window by introducing a variable duration blank screen between the stimulus and the crossed-disks mask, with stimulus duration fixed at 50 ms; the integration window was more than 150 ms in rough agreement with published estimates measured using sinusoidal depth modulation in time.

32.15, *11:45 am*

Hysteresis in Stereoscopic Surface Interpolation: A New Paradigm

Christopher Tyler[1](cwt@ski.org), Navdeep Gill[1], Spero Nicholas[1]; [1]Smith-Kettlewell Eye Research Institute

INTRODUCTION. One of the most fascinating phenomena in stereopsis is the profound hysteresis reported by Fender and Julesz (1967), in which the depth percept with increasing disparity persisted long past the point of depth recovery with decreasing disparity. To control retinal disparity without vergence eye movements, they stabilized the stimuli on the retinas with an eye tracker. We now report that stereo hysteresis can be observed simply by rotating the binocular stereogram image. As the image rotates, the horizontal disparities rotate to become vertical, then horizontal with inverted sign, then vertical again before returning to the original orientation. The depth shows an interesting popout effect, almost as though the depth was rapidly switching on and off, despite the inherently sinusoidal change in the horizontal disparity vector. METHODS. This stimulus was set up electronically in a circular format so that the random-dot field could be dynamically replaced, eliminating any cue to cyclorotation. Noise density was proportional eccentricity to fade the stimulus near the zero-disparity fixation target, allowing us to verify that fixation was held accurately at zero disparity. RESULTS AND DISCUSSION. For both the invariant and the dynamic noise, profound hysteresis of many seconds delay was found in eight observers for both the onset and offset of the perceived depth surface. This hysteresis was far longer than the <1000 ms reaction time to respond to changes in disparity. A similar hysteresis was obtained for depth popout from vertical disparity modulation of a fixed horizontal disparity. Conversely, sinusoidal modulation of the horizontal disparity to match the horizontal vector component of the disparity rotation did not show the popout effect, which thus seems to be a function of the interaction between horizontal and vertical disparities and is attributable to the time course of surface interpolation processes for the perceived depth structure.

Acknowledgement: AFOSR grant #FA9550-09-1-0678

32.16, *12:00 pm*

Depth Spreading through Empty Space Induced by Sparse Disparity Cues

Xintong Li[1](li29@tcnj.edu), Abigail E. Huang[1], Eric L. Altschuler[1], Christopher W. Tyler[2]; [1]New Jersey Medical School, [2]Smith-Kettlewell Institute

Neon color spreading is a well established visual illusion in which a colored inducing figure evokes the impression of colored glow spreading through empty (achromatic) regions of space between the colored inducing lines, with a sharp color border around the edge of the induced figure. We asked whether there is a depth spreading effect analogous to the color spreading, whereby the perceived depth of the figure region would form a surface at the depth of the inducing lines with a sharp depth border along the perceived figure boundary. Two alternatives are possible. The inducing lines could be seen as isolated in depth with no effect on the surrounding space, or the lines could induce a smooth surface completion with the background, corresponding to smoothness constraint on stereoscopic depth reconstruction. The perceived depth was estimated by selection of which of a set of points matched the perceived the perceived depth of the surrounding space at selected locations across the image. For a group of four subjects, the perceived depth showed strong adherence to the depth of the inducing lines, forming a sharp depth edge at the boundary of the induced figure (a disk) although it was running through empty space. The depth induction was not limited to frontoparallel surfaces, being equally compelling when the surface slanted horizontally in depth. There was no evidence of the operation of a smoothness constraint across the perceived depth edge, although the edge itself represents a form of anisotropic continuity constraint on the form of the induced depth structure. The results place strong constraints on the properties required models of depth reconstruction of object structures implied by sparse disparity cues.

32.17, *12:15 pm*

Depth from diplopic stimuli without vergence eye movements

Arthur Lugtigheid[1](lugtigheid@gmail.com), Laurie Wilcox[2], Robert Allison[3], Ian Howard[1]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Department of Psychology, Centre for Vision Research, York University, Toronto, Ontario, Canada, [3]Department of Computer Science and Engineering, Centre for Vision Research, York University, Toronto, Ontario, Canada

Sunday AM

See page 3 for Abstract Numbering System

It is well-established that stereoscopic depth is obtained over a large range of retinal disparities, including those that produce diplopia (double images). Under normal viewing conditions, observers make vergence eye movements to minimize large disparities, and it has been suggested that observers judge depth sign for diplopic stimuli by monitoring the vergence signal. Here we ask if vergence eye movements are required to judge depth order (disparity sign) of diplopic stimuli. We created an open-loop stimulus by presenting stereoscopic afterimages, for which eye movements cannot provide feedback about depth sign or magnitude. We produced afterimages of line stereograms consisting of precision-milled slits in aluminum plates that were back-illuminated by a photographic flash. Each half-image consisted of two thin (1x10mm) vertical slits, positioned above and below a small (1mm) fixation LED. The half-images were viewed through a modified mirror stereoscope, so that the fused image formed two narrow bars in the mid-sagittal plane. On each trial, the upper and lower bars were displaced in depth by one of five equal and opposite disparities (two in the range of fusion, one zero and two that were diplopic). After each presentation, observers (n=15) judged which bar was closer to them. Observers reliably judged the sign of disparity for both diplopic and fused images. We conclude that judgments of disparity sign for diplopic stimuli do not depend on extraretinal information, but are recovered directly from the retinal disparity signal.

Acknowledgement: Natural Sciences and Engineering Research Council and the Ontario Centres of Excellence

Attention: Tracking

Sunday, May 13, 10:45 - 12:30 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Alex Holcombe

32.21, *10:45 am*

The world's spinning backwards because it's too fast to track

Derek Arnold[1](darnold@psy.uq.edu.au), Sam Pearce[1], Welber Marinovic[1]; [1]School of Psychology, The University of Queensland, Australia

Illusory motion reversals can happen when looking at a repetitive pattern of motion, such as a spinning wagon wheel. To date these have been attributed to either a form of motion after-effect seen while viewing the adapting stimulus or to the visual system taking discrete perceptual snapshots at a rate of ~10Hz. Here we present evidence that is inconsistent with both proposals. First we explore what adaptation TF is optimal for inducing illusory reversals. We find that this conforms to a low-pass function that is not tuned for direction, ruling against a motion after-effect account. We also show that the optimal test TF for illusory reversals is stimulus dependent, being lower for colour relative to luminance-defined motion. This is inconsistent with an account based on a constant rate of discrete perceptual snapshots. Instead we posit that illusory reversals happen when an attention tracking system intermittently fails to keep up with a stimulus, due to adaptation of a low-pass TF channel. According to this, the maximal rate at which repetitive elements can be tracked via attention should be subject to adaptation. We show that this is true, with participants better able to track elements after adapting to relatively fast motion and worse after adapting to slower movement. Overall, our data are consistent with human motion perception being driven by two relatively independent mechanisms, which at times can provide conflicting signals.

Acknowledgement: The Australian Research Council

32.22, *11:00 am*

A hemisphere-specific attentional resource supports tracking only one fast-moving object.

Wei-Ying Chen[1](wingchen0125@gmail.com), Alex O. Holcombe[1]; [1]The University of Sydney

Playing a team sport or taking children to the beach involves tracking multiple moving targets. Resource theory asserts that a limited resource is divided among targets, and performance reflects the amount available per target. Holcombe and Chen (2011) validated this with evidence that tracking a fast-moving target depletes the resource. Using slow speeds Alvarez and Cavanagh (2005) found the resource consumed by additional targets is hemisphere-specific. They didn't test the effect of speed, and here we tested whether speed also depletes a hemisphere-specific resource. To put any speed limit cost in perspective, we modeled a "total depletion" scenario- the speed limit cost if at high speeds one could not track the additional target at all and had to guess one target. Experiment 1 found that the speed limit for tracking two targets in one hemifield was similar to that predicted by total depletion, suggesting that the resource was totally depleted. If the second target was instead placed in the opposite hemifield, little decrement in speed limit occurred. Experiment 2 extended this comparison to tracking two vs. four targets. Compared to the speed limit for tracking two targets in a single hemifield, adding two more targets in the opposite hemifield left the speed limit largely unchanged. However starting with one target in both the left and right hemifields, adding another to each hemifield had a severe cost similar to that of the total depletion model. Both experiments support the theory that an object moving very fast exhausts a hemisphere-specific attentional tracking resource.

Acknowledgement: ARC FT0990767 to AOH

32.23, *11:15 am*

Attentional selection increases the refresh rate of perception: Evidence from multiple-object tracking

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Selective attention enhances accuracy and speeds responses in many perceptual tasks. In some cases, these enhancements may be probabilistic, e.g. reflecting an increased likelihood that an attentional spotlight will sample from selected (rather than background) objects at any given moment. Might attentional selection also lead to qualitatively different sampling? Here we explore the possibility that selection can alter the functional 'refresh rate' of perception. While fixating, observers tracked 2 out of 5 objects in a simplified multiple object tracking task. As they moved, the objects also rapidly changed colors (4-12 times per second, varied from trial to trial), and participants simultaneously monitored for probe events in which any 2 objects' changing colors momentarily became synchronized. Target-target probe detection was dramatically enhanced relative to target-distractor or distractor-distractor probe detection at every rate tested, with target-target detection on 12 Hz trials roughly equivalent to target-distractor (or distractor-distractor) detection on 4 Hz trials. (And this effect replicated for multiple visual features, including rapid shape changes.) Critically, baseline performance (as revealed by a control experiment with probe detection but no tracking) was also just as low as the target-distractor and distractor-distractor conditions, indicating that the selection effect reflects target enhancement rather than distractor impairment. Nontemporal accounts were unable to predict these data. For example, a deflationary interpretation wherein task demands simply kept observers from processing distractors would predict worse performance for distractor-distractor (and target-distractor) probes relative to baseline probes — but this was not observed. Data from additional control experiments also ruled out interpretations based on sampling of selected objects that was no more frequent, but instead was more synchronous, or involved higher-resolution samples. These data collectively suggest that attentional selection leads to more frequent sampling of selected objects — an increase in the functional refresh rate of perception.

32.24, *11:30 am*

Capacity & Resolution of Multi-object Tracking

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Attentional tracking is traditionally assumed to be capacity-limited in that only a few discrete items can be tracked (e.g., Pylyshyn's FINST-based visual index theory). However, some recent studies suggested that attention to spatiotemporal objects is only limited by a pool of resources that can be allocated flexibly to track a small number of items with high resolution or a large number of items with low resolution. In a multi-object tracking task, observes tracked a variable number of targets among distractors in random motions for 4.5 seconds, and then reported whether a probed item was one of the tracked items on a 6-point confidence scale. Receiver operating characteristic (ROC) curves were constructed from the confidence data. Two independent parameters, modeled from the slot+averaging hypothesis (Zhang & Luck, 2008), were estimated from ROCs, to represent resolution of the tracked items (d prime) and the probability that the probed item is tracked (PT). We found that both PT and resolution can be quantitatively accounted for by the slot+averaging model. That is, the maximum number of items that can be tracked is capped at about 3.5 at set size four and six, suggesting limited capacity. In addition, resolution of tracking is significantly better at set size two, when more than one attentional indices can be allocated to track a single item, compared to set size four & six where only one spatial index can be allocated to one item. In Experiment 2, we manipulated the speed of the random motion. PT significantly decreased from slow speed to intermediate speed, but not from intermediate speed to fast speed. In contrast, resolution of the tracked item remained constant across motion speeds. Together, these results suggest that FINST-based visual indices are based on a limited set of fixed-resolution representations.

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32.25, *11:45 am*

Revisiting Target Merging in Multiple Object Tracking (MOT)

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Introduction: What counts as an object for the purposes of MOT? Tracking accuracy substantially decreases in MOT when each target is joined via a connector to a distractor, an effect known as target merging (Scholl et al., 2001). This occurs because each conjoined target-distractor pair is perceived as a single, indivisible object. Altering the connector used influences the degree of target merging and provides an opportunity to investigate the nature of visual objecthood in MOT. However, the Scholl et al. (2001) study had a potential confound: The target-distractor pairs continuously changed length, which in itself has been found to disrupt tracking (VanMarle & Scholl, 2003). Our experiments addressed this issue. Method & Results: In the baseline condition, the target-distractor pairs were not conjoined (i.e. a standard MOT paradigm). Tracking accuracy was high. The bars condition was identical to the baseline condition except that each target-distractor pair was conjoined by a solid bar. Tracking accuracy was greatly reduced even though the target-distractor pairs did not change length. The luminance condition was identical to the bars condition except that luminance differences were used to make the targets distinct from the connecting bars. Tracking accuracy was still much lower than in the baseline condition. In the dumbbells and pie-shaped conditions the connecting bars were altered in a way that was expected to abolish target-merging effects (Scholl et al., 2001). Surprisingly, tracking accuracy was still much less than in the baseline condition. In the occlusion condition, the centres of the connecting bars were occluded. Tracking accuracy was again much poorer than in the baseline condition. Conclusion: We found that target merging effects occurred even when the length of the target-distractor pairs was held constant. In fact, the effects were more robust than previously reported, occurring even when the targets were made perceptually distinct from the connecting bars.

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32.26, *12:00 pm*

Splitting attention slows attention: poor temporal resolution in multiple object tracking

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When attention is split into foci at disparate locations, the minimum size of the selection focus at each location is larger than if only one location is targeted (Franconeri, Alvarez, & Enns, 2007)- splitting attention reduces its spatial resolution. Here we tested temporal resolution and speed limits. STIMULUS. Three concentric circular arrays (separated by large distances to avoid spatial interactions between them) of identical discs were centered on fixation. Up to three discs (one from each ring) were designated as targets. The discs orbited fixation at a constant speed, occasionally reversing direction. After the discs stopped, participants were prompted to report the location of one of the targets. DESIGN. Across trials, the speed of the discs and the number in each array was varied, which jointly determined the temporal frequency. For instance, with 9 objects in the array, a speed of 1.1 rps would be 9.9 Hz. RESULTS. With only one target, tracking was not possible above about 9 Hz, far below the limits for perceiving the direction of the motion, and consistent with Verstraten, Cavanagh, & LaBianca (2000). The data additionally suggest a speed limit, with tracking impossible above 1.8 rps, even when temporal frequency was relatively low. Tracking two targets could only be done at lower speeds (1.4 rps) and lower temporal frequencies (6 Hz). This decrease is approximately that predicted if at high speeds and high temporal frequencies, only a single target could be tracked. Tracking three yielded still lower limits. Little impairment was seen at very slow speeds, suggesting these results were not caused by a reduction in spatial resolution. CONCLUSION. Splitting attention reduces the speed limits and the temporal frequency limits on tracking. We suggest a parallel processing resource is split among targets, with less resource on a target yielding poorer spatial and temporal precision and slower maximum speed.

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32.27, *12:15 pm*

Further evidence for automatic, feature-based grouping in multiple object tracking

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Background: In a multiple object tracking task, if half the targets and half the distractors share a common feature, and remaining objects share an alternate feature, tracking performance is impaired relative to a condition in which all objects share the same features (Mettler et al., 2011). Tracking decrements appear to be due to automatic perceptual grouping. However, an alternative hypothesis is that the heterogeneity of target features impairs tracking, independent of distractor features. According to this hypothesis, even if distractor features are changed so that targets cannot group with distractors, tracking performance should continue to be poor. Method: To consider this possibility, we compared two grouping conditions for 4 different features: color, shape, size and all features combined. In both conditions, two of four targets possessed one grouping feature (e.g. red in the color condition) and two possessed an alternate feature (e.g. green). In a 'Sharing' condition, distractors possessed the same features in the same distribution. In a 'Diversity' condition, distractors possessed two features not present in the targets (e.g. yellow and purple). One target and one distractor (always distinct featurally) were presented in each screen quadrant. After targets flashed briefly, each pair orbited a central point within its respective quadrant. Participants attempted to identify each target with a mouse. Results: Overall performance was worse for the Sharing condition than for the Diversity condition ($p<.001$). This comparison was significant for all features except size ($p = .066$). Conclusion: Superior tracking in the Diversity condition argues that previously observed tracking decrements in feature sharing conditions cannot be ascribed to the effects of feature diversity. These findings support our hypothesis that shared features lead to automatic feature-based grouping between targets and distractors.

Sunday AM

See page 3 for Abstract Numbering System

Motion: Biological I

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

33.301 The global and local effects on biological motion perception in squirrel monkeys (Saimiri sciureus)

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When viewing simple two-point configurations, we have a strong propensity to interpret the moving points as though they were attached to a rigid rod moving in depth (Johansson, 1973). We can also perceive the movement of a human body from just the motions of joints using point-lights (Biological Motion). Regardless of living or no-living object, we perceive the structure of an object in motion. But even if presented a single geometric, we would be able to perceive it as an animate object motion (Tremoulet & Feldman, 2000). We are focusing on the question how the non-human animal can easily discriminate a living object from a non-living object and are focusing on the motion property of object. We investigated whether squirrel monkeys discriminate the stimuli made by the global or local motion information, using the method of sensory reinforcement. We used the moving objects which had two shapes, mealworm shape and mosaic mealworm shape. These stimuli consisted of four motion conditions (global plus local motion, global only, local only, static image). Monkey was required to touch the screen. After the touch, the stimulus was presented on the screen for 3 sec. The stimulus was changed to the next one when 30 sec passed without touching. Thus, monkey could control the viewing time of the stimulus by himself. Monkey had higher performances under the condition of global plus local motion and under the condition of static image of mealworm than other conditions. It suggested that the monkey discriminated the natural movement and the static image of mealworm from the other motions of mealworm. It seems that the unnaturalness of motion without the global or local motion information decreases its likelihood of living object.

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33.302 The effect of stimulus contrast on action discrimination

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Determining the contributions of the body form and motion cues to the perception of biological motion is important for understanding how we recognize actions. In this study we examined the effects of contrast on the discrimination of different point-light human actions. Participants (N=11) determined which of four simultaneously presented actions (boxing, leaping, running, or walking) matched a central action. The central action was always intact point-light biological motion and at 100% contrast, while the four choice actions varied in contrast and were either intact point-light biological motion, scrambled biological motion, or static body form. Results showed a similar increase in accuracy with increasing contrast for the intact and scrambled biological motion stimuli. This increase occurred at lower contrast levels for intact and scrambled biological motion relative to the static form stimuli. Even at lower contrast levels, however, accuracy was higher for intact than for scrambled biological motion stimuli, and remained so until the highest contrast level. Accuracy was higher for intact and scrambled biological motion than static form at all contrast levels except the highest. These results support previous findings showing that the perception of biological motion is contrast-dependent. Our results provide new details about the contrast-dependence of form and motion contributions to the discrimination of human actions.

33.303 Intersubject variability in the use of form and motion cues during biological motion perception

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We sought to investigate sources of intersubject variability in the use form and motion cues during biological motion perception. We administered a battery of psychophysical and cognitive tasks to assess the relationship between sensitivity of these perceptual mechanisms and other behavioral measures. Discriminating facing direction of a point light walker can be achieved using form cues alone, whereas discriminating walking direction cannot (Lange & Lappe, 2007). In order to differentiate between form and motion processing, we administered both of these tasks to the same individuals (plus non-biological object motion controls). Point-light stimuli were embedded in a variable number of noise dots, and subjects had to determine which direction the target faced or moved (depending on the task). Thresholds were estimated adaptively (Watson & Pelli, 1983). The tasks in our battery included perceptual measures such as motion coherence thresholds, visual and motor imagery, and measurements of social traits such as empathy and personality. We hypothesized that tasks sharing perceptual and neural resources with the mechanisms for biological form and motion processing would correlate significantly with perceptual sensitivity as measured by our tasks. The walking direction task, which relies on motion processing, significantly correlated with third-person visual motor imagery. Non-biological object motion direction also correlated with this measure. However, no significant correlations were found with non-motor visual imagery. In line with embodied theories of action perception, first-person visual motor imagery was significantly correlated with the biological walking direction task, but not its non-biological counterpart. No significant correlations were observed for the facing direction experiments, providing evidence that different perceptual resources contribute to form and motion processing in biological motion perception.

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33.304 Efficiencies for parts and wholes in biological motion perception

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While some previous studies have examined how well humans can process certain subsets of points in a point-light walker (PLW) stimulus (e.g., Mather, Radford & West, 1992; Troje & Westoff, 2006), none has explored whether differences in information content exist across subsets of points within PLW stimuli. As a result, it is difficult to draw strong conclusions about the relative ability of human observers to process points located at one part of the body (e.g. the feet) relative to another (e.g. the hands). To begin to address this issue, we employed ideal-observer analysis to compute the efficiency with which human observers use information when processing different parts of PLW stimuli. Specifically, we measured both human and ideal observer contrast energy thresholds for left-right walking discrimination of PLW stimuli in 7 related conditions: a set of 3 'isolated' conditions in which the stimuli contained only feet, hands or knees; a set of 3 complementary 'missing' conditions in which the stimuli were missing their feet, hands or knees; and a 'complete' condition in which the stimuli contained all body points. Ideal observer thresholds did not vary significantly across conditions, indicating that the amount of information carried by PLW stimuli does not depend on whether a given body location is either isolated or missing. For human observers, average efficiencies (ideal threshold/human threshold) were similar across each of the 'missing' conditions as well as the 'complete' condition, and were also similar across each of the 'isolated' conditions. However, absolute efficiencies were over a factor of 2 greater in the 'isolated' conditions relative to the 'missing' and 'complete' conditions. While it remains unclear why efficiency is so much greater for isolated body locations, our results show that human observers process the information contained in the hands, feet and knees with approximately equal efficiency.

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33.305 "What" and "when" in action prediction

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Sunday AM

Research shows that humans can predict future actions with high temporal precision (Graf et al., 2007). We hypothesized that in many real-life situations (particularly when observing an interaction between others), it may be more important to predict what will happen in the future rather than precisely when it will happen. In Experiment 1, we showed subjects brief movie sequences of two interacting actors, or just one of those actors, followed by a 400ms occluder. Two static figures then followed: a target depicting the posture as the action would have appeared had it continued for 400ms, and a distractor posture that occurred earlier or later than the elapsed time. Observers were asked to select the figure representing a correct action continuation. When the distractor had occurred in the preceding movie sequence, observers were more accurate in the interaction condition than in the single-actor condition. This result indicates that in the interaction condition, observers could better distinguish between backward and forward action trajectories. However, when target and distractor were both sampled from future postures, subjects were more accurate in the single-actor condition, suggesting a greater temporal precision in the single-actor condition. Experiment 2, was similar in design, but observers were asked to indicate whether after the occlusion the actor, sampled from the future action trajectory, was rotated in depth. Accuracy was higher in the interaction condition than in the single-actor condition, indicating more accurate "what" estimates in the former condition. However, postures that were a natural temporal progression and delayed/advanced postures resulted in similar performance, indicating loss of temporal precision. Overall, these findings suggest that humans excel in predicting when an action posture will occur in the future when viewing a single actor, but are better able to predict what posture will occur based upon a meaningful interaction between two actors.

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Sunday AM

33.306 **Just walk away: Reference repulsion in the perception of crowd behavior**

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Humans often behave in crowds, and as such, perceiving crowds may be important for typical social interaction. Perceiving crowds headed toward one's self may be especially important, so much so that the visual system may devote extra resources for this purpose. If this hypothesis were true, humans should show increased sensitivity for perceiving oncoming headings. Furthermore, as a result of this sensitivity, humans should experience a repulsive perceptual effect around the categorical boundary of leftward/rightward oncoming motion. We tested these predictions and found evidence for both. First, observers were especially sensitive to the heading of an oncoming crowd (or an individual); estimates of a crowd's heading were more precise near the category boundary of leftward/rightward motion. Second, we found a strong repulsion effect around the category boundary; a crowd walking approximately toward the observer was perceived as being repelled away from straight ahead (e.g., a crowd heading 5º to the left of an oncoming heading was perceived as heading 10º to the left). This repulsive effect was especially strong for crowds, particularly those with variability in the headings of individuals. This latter effect is predicted by narrowed heading tuning near the category boundary. Further experiments showed that the repulsion effect requires integration of both local motion and human form, suggesting an origin in high-level stages of visual processing. Repelling a crowd's heading away from the leftward/rightward boundary may be important for avoiding head-on collisions. Similar repulsive effects may underlie categorical perception with other social features. Overall, our results show that crowds of walkers are categorically perceived, with improved sensitivity at the category boundary and a concomitant repulsion effect.

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33.307 **Perceived direction of human, robot and point-light walkers modulated by head direction**

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Perception of human walkers' direction is important for social interaction. Observers infer walker's trajectory from his gaze direction (Nummenmaa, Hyona & Hietanen, Psychological Science, 2009). We reported that perception of walker's direction was accurate with motion display only for 117 ms (Sato et al., ECVP 2008), however the gaze did not affect it. We aimed to investigate effects of head direction and body appearance on low-level perception of walker's direction. We presented a walker stimulus, whose direction was randomly chosen in the rage of left and right 24 deg to observers, for 500 ms (two steps per second). The first walking phase was randomly chosen for every trial. The direction of head was either left 9 deg to, right 9 deg to, or same as the body. We varied body and head appearances, and combined them to make a stimulus. Body was either a gray-scale computer graphics of human, a robot made by replacing body parts with 15 boxes, or point lights at 18 joints as biological motion stimulus. Head was either gray-scale human face or boxes-made robot face. Ten naive observers were asked to adjust direction of a pin-shape probe to match perceived walking direction of the body irrespective of the head. We found a significant main effect of head direction, and a significant interaction of head direction and body appearance. Perceived direction of walker was modulated in the direction of head, and the modulation was larger with point-light body than human and robot. Response variance was larger for point-light walkers than human and robots. A subsequent experiment revealed that the same effects occurred for inverted walkers. These results suggest that perception of walker's direction is implicitly and automatically affected by head direction, and the effect of head direction is strong when the perceptual reliability of body direction is low.

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33.308 **Exploring Individual Differences in Perceptual Biases in Depth-Ambiguous Point-Light Walkers**

Adam Heenan[1](adam.heenan@queensu.ca), Nikolaus F. Troje[1]; [1]Department of Psychology, Queen's University

Biological motion stimuli, depicted as orthographically projected point-light displays, do not contain any information about their orientation in depth. For instance, the fronto-parallel projection of a point-light walker facing the viewer is the same as the projection of a receding walker. Even though inherently ambiguous, observers tend to interpret such walkers as facing the viewer. While some have suggested that this facing-the-viewer (FTV) bias exists for sociobiological reasons, there is currently a lack of evidence to support this claim. The goal of this study was to correlate individual differences in psychological characteristics (i.e., anxiety, depression, and personality traits) with the FTV bias. We hypothesized that the FTV bias would be positively correlated with measures of anxiety, as we rationalized that more anxious individuals would be more worried about misinterpreting an approaching person as a receding one. In addition to measuring the socially loaded FTV bias, we also assessed the degree of a socially neutral bias: The tendency to perceive the walker from above rather than from below (i.e., the viewing-from-above, or VFA, bias). None of the characteristics correlated with the FTV bias, but we found that anxiety (both as a current mood state and as a personality trait) was negatively correlated with the VFA bias. More anxious individuals were less likely to perceive walker stimuli as if viewing them from above. This result is discussed in the context of other studies which seem to indicate that anxiety impacts the use of statistical priors to disambiguate visual stimuli.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

33.309 **Perceived naturalness of human motion depends on internal consistency**

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Human motion is constrained by inertial and gravitational forces. In order to move energetically efficient our motor control systems must take these constraints into account when producing body movements. For instance, when changing walking speed a whole array of associated kinematic parameters also change their values. These changes are subtle but systematic and we hypothesize that the visual system knows about them and evaluates them when visually assessing another persons movements. The motion of 50 male and 50 female participants was captured while they were walking on a treadmill at three different speeds (veridical speeds). Each sample was then presented as a point-light display and played back at the same three speeds (playback speeds). In that way, we created for each of the 100 walkers a set of 9 point-light displays (3 veridical x 3 playback speeds), only three of which displaying the person at the same speed at which he/she was recorded. Observers were then asked to use a Likert scale to rate how natural the displays appeared. Significant main effects of veridical speed and playback speed were found. The highest veridical speed and the medium playback speed were perceived to be most natural. Most importantly, we found a highly significant interaction between these two factors, indicating that observers very sensitively detected the inconsistencies between veridical speed and playback speed. Displays in which veridical and playback speed matched were always rated to be the most natural. This impressive sensitivity to the very subtle dependency of the kinematics of walkers on their speed demonstrates that the visual system employs implicit knowledge about the biomechanic relations between different kinematic parameters. It also exposes the level of sophistication required for biomechanical models that can generate convincingly realistic character animation in computer graphics.

Acknowledgement: NSERC, CIfAR

33.310 **The temporal structure of social reflexive orienting from point-light biological motion**

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Human observers infer the attended direction of others based on head and gaze orientation, which results in covert and unintended shifts of attention. Known as social reflexive orienting, peripheral targets preceded by directed gaze speed detection of cued targets, even when subjects are aware that the cues are not predictive (Friesen & Kingstone, 1998). Recently, researchers demonstrated improved peripheral target discrimination following a point-light biological motion sequence when the target location was cued by the facing direction of the walker (Shi et al., 2010). Here we explore two aspects of biological motion social reflexive orienting: the evolution of covert orienting over time, and the interaction between symbolic (i.e. arrows) and social orienting cues. Methods. Subjects viewed a stationary array of oriented arrows or a point-light profile view walker (4x1.5deg visual angle). Subjects reported the position (left or right) of a 93ms target that appeared after a stimulus onset asynchrony (SOA) of 70-850ms. The subjects were informed that the facing or pointing direction of central cue was not predictive of the target location. In a second set of experiments, the subjects performed the same task with biological motion animations constructed from small arrows (instead of point-lights). Results. Trials with targets validly cued by the stationary arrows and biological motion resulted in RTs approximately 20ms faster than invalid trials. The arrow-driven reflexive orienting effect was apparent at nearly all SOAs, while orienting from biological motion was evident at early (93-350ms) and late (650ms) intervals. Both stimuli induced an inhibition of return (longer RT for validly cued trials) at 500ms SOA. Walkers constructed with oriented arrows effectively cancelled any reflexive orienting. Conclusions. The timecourse of reflexive orienting in biological motion differs from that generated by arrows. This social orienting cue, however, is fragile and relatively weak in comparison to symbolic orienting cues.

Acknowledgement: This work is supported by NSF BCS0748314

33.311 **Psychosocial Resources Affect Biological Motion Perception**

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Observer characteristics can alter perception. For example, the Resources and Perception Model (RPM; Harber et al., 2008) asserts that psychosocial resources, including social support and self-esteem, can attenuate responses to threat and enable more accurate perception. Supporting research indicates that an observer's psychosocial resources can reduce the perceived steepness of hills (Schnall et al., 2008) and the perceived distance to threatening objects (Harber et al.., 2011). It is unknown whether psychosocial resources influence perception of biological motion. Two studies examined how depleted psychosocial resources influence the detection and analysis of emotional point-light walkers (PLWs). In both studies, participants' psychosocial resources were either lowered or left unchanged by engaging in an online game of catch (Cyberball, Williams & Jarvis, 2006). Participants in the ostracized condition were largely excluded from the game, whereas control participants were included throughout the four-minute manipulation. In study 1, 60 naïve participants (65% female) viewed 3 second masked point-light displays containing either a coherent or a scrambled walker that expressed anger, happiness, or a neutral emotional state (Chouchourelou et al., 2006) and reported whether a coherent walker was present in each display. Detection sensitivity and response bias were assessed. Ostracized participants had reduced detection sensitivity, but only if they lacked social support and self-confidence. In study 2, 63 new participants (75% female) viewed masked point-light walkers (stimulus duration = 3000ms) and identified the depicted emotion. Reaction time and accuracy were recorded. Social support and ostracism interactively influenced accuracy at identifying emotion. Ostracized participants were less accurate at identifying emotion, but only if they lacked social support. These results indicate that psychosocial resources are important for accurate biological motion perception and further suggest that trait resources can attenuate social threat from ostracism to enable accurate perception.

33.312 **Position-specific and position-invariant action adaptation correlates with the Autism Spectrum Quotient**

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Humans show position-specific adaptation to simple stimuli (e.g., oriented bars), but show position-invariance to complex stimuli (i.e., faces). Such distinguishing characteristics of adaptation can potentially reveal the neural mechanism underlying visual processing. We investigated position-specific and position-invariant adaptation to biological motion. Subjects were adapted to walker or runner point-light stimuli for 6 seconds and then were given a 1-s test stimulus (a morphed action intermediate between walker and runner). Subjects reported the perceived action of the test. An Autism Spectrum Quotient (AQ score) was acquired, which measures the degree to which an adult with normal intelligence has traits associated with Autism Spectrum Disorder (ASD). We measured the percentage of trials in which a runner was reported. We computed the difference between conditions with walking and running adaptation to measure the "adaptation effect". There were significant adaptation effects when adapting and testing locations were identical (i.e., position-specific adaptation). When adapting and testing locations differed, i.e. position-invariant adaptation, we found an overall non-significant effect, which was however significantly negatively correlated with the AQ score. Splitting the subjects along the median AQ score, we found that the low-AQ group (with fewer autistic traits) showed significant position-invariant adaptation, while the high-AQ group showed no position-invariant adaptation. Conversely, adaptation effects at presumably lower visual levels (acquired by subtracting the position-specific effect from the position-invariant effect) were significantly positively correlated with AQ score, suggesting that subjects with more autistic traits had increased adaptation at low visual processing levels. Our data show both position-specific and position-invariant adaptation to biological motion. Whether adaptation effects transfer to other locations is correlated with the AQ score. This result is consistent with the hypothesis that people with ASD tend to focus more on low-level stimulus characteristics, and have impaired processing of high-level (position-invariant) aspects of biological motion.

Acknowledgement: This research was supported by NSF grant BCS-0843880

Development: Lifespan

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

33.315 **Perceptual and cognitive performance in Indian female tea-pluckers are improved with iron-fortified salt**

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Iron deficiency (ID) is the most prevalent micronutrient deficiency in the world, and differentially affects women of reproductive age. Both human and animal studies have documented substantial deficits in individual perceptual and cognitive functioning with ID and improvements with iron repletion. Previous work is limited by a lack of specificity for perceptual and cognitive assessment. The present study examines the effects of ID and repletion in 248 female tea-pickers of reproductive age (18-55 y) in West Bengal, India. Subjects were part of a 10-month double-blind, randomized controlled intervention with salt double-fortified with iodine and iron (DFS) and iodized salt (control). Six measures of perceptual and cognitive performance---simple reaction time, 2 measures of visual detection, 2 measures of attention, and recognition memory---were selected for their ability to selectively examine perceptual and cognitive functioning relative to iron status and to job performance. We previously reported (VSS '11) substantial improvements in perceptual and cognitive performance in women receiving DFS. We here present further analyses linking improvements in specific aspects of perceptual and cognitive performance to positive changes in iron status, baseline iron status, and amount of DFS consumed. The results include the effects of iron status on individual perceptual and cognitive functioning, and of body iron repletion on the resolution of perceptual and cognitive deficits caused by ID. Additionally, we examine the relationship between amount of iron consumed and perceptual and cognitive functioning, and the dependence of this relationship on baseline iron status. This work has important implications for dietary iron and therapy recommendations, and suggests that perceptual and cognitive functioning must be considered when determining the health and economic losses due to ID. Support: Mathile Institute, Micronutrient Initiative, and NSF.

Acknowledgement: Mathile Institute, Micronutrient Initiative, and NSF.

33.316 **Measuring Spatial Contrast Sensitivity in Adults and Children by Combining Sine Waves with Landolt Cs.**

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Purpose In the quest to develop a contrast sensitivity test that combines experimental rigor with clinical ease of use and interpretability, we (VSS 2009) reported on a new prototype test which consists of classic Landolt C optotypes that are created with luminance modulated sine-waves. In the present work, we have improved the technical aspects of this test and now provide some normative data from larger samples of children and adults. Methods: The modified test consists of 6 charts, each containing rows of Landolt Cs which, from the outside to the inside edge of each C, modulate sinusoidally at 1 of 6 spatial frequencies (0.37, 0.75, 1.5, 3, 6 and 12 cy/deg). With each successive row, optotypes decrease in contrast from 40% (2.5 CS units) to 0.5% (200 CS units) in equal log steps. 110 preschoolers (3-5 yr) and 65 adults were tested monocularly at 3m with all 6 charts. For comparison, adults were also tested with commercially available FACT and Vector Vision sine-wave CS tests. Results: All adults and 95% of preschoolers completed the entire test (M = 4 min) and each subject generated an interpretable contrast sensitivity function (CSF). Distributions of CS at each spatial frequency were distributed normally with mean performance (across SF) increasing slightly from 38 CS units at 3 years to 51 units at 5 years to 66 units in adulthood, a value very consistent with both the commercial FACT and Vector Vision CS tests. Conclusions: The new sine-wave Landolt C test of contrast sensitivity appears to be a valid and time-efficient tool for measuring full-spectrum contrast sensitivity in young children and adults. The ease of responding to the Landolt target yields both definitive responses and clear estimates of contrast thresholds. Moreover, the software that we have developed to produce Landolt targets is easily modified to allow additional estimates of high and low contrast visual acuity.

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33.317 **Age-related changes in suprathreshold contrast perception in the upper and lower visual field: Effects of temporal/spatial frequency and contrast**

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Leone, Blakeslee & McCourt (VSS 2011) reported a significant age-related reduction in the perceived contrast of gratings in the lower versus upper visual field, in free viewing. We extend these findings by assessing suprathreshold contrast perception at additional spatial and temporal frequencies, under conditions of central fixation. In Experiment 1 participants (N=64) matched the contrast of gratings (1°x 40°; 0.0625 or 1.875 c/d; 5 or 50% contrast) in the upper and lower visual fields (±7.5° eccentricity) while maintaining central fixation. As previously found in free viewing, at all contrasts and spatial frequencies there was an age-related reduction in the perceived contrast of gratings in the lower versus upper visual field. Experiment 2 replicated Experiment 1 except that grating contrast was temporally counterphased at 1 or 4 Hz. Temporal modulation eliminated the age-related visual field processing asymmetry found for static stimuli. In the low contrast, low spatial frequency condition (5%; 0.0625 c/d), temporal contrast modulation at both 1 and 4 Hz actually reversed the age-related reduction in perceived contrast in the lower visual field such that perceived contrast in the lower versus upper visual field increased with age. These results are discussed with respect to an age-related magnocellular pathway deficit where sensitivity loss is greatest for static stimuli, and where disuse supersensitivity may result in compensatory (high gain) responses to preferred (temporally modulated) stimuli.

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33.318 **Magnified visual feedback alters the neural activation of muscles and impairs motor control and learning in older adults**

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There is substantial evidence that magnification of visual feedback impairs the ability of older adults to perform force tasks with precision. We extend the literature to the effects of visual feedback on the neural activation of muscles and motor learning during movements. We performed two experiments to determine whether magnified visual feedback in older adults alters their neural activation of muscles and impairs motor control and learning. In Experiment 1, 12 young and 10 older adults attempted to accurately match a sinusoidal target by abducting-adducting their index finger or dorsi/plantar flexing their ankle at three distinct visual angles (0.25°, 1° and 5.4°). In Experiment 2, 30 older subjects participated. Twenty subjects trained on the same sinusoidal task with their ankle joint for 2 weeks (5 sessions x 60 trials/session) with either reduced (0.25°) or magnified (5.4°) visual feedback. The other 10 served as the control group. Retention and transfer tasks were tested post training. For both experiments, the agonist muscle activity was measured using surface electromyography. Experiment 1: Magnified visual feedback exacerbated the differences in movement control between young and older adults for both limbs. The oscillatory activation of the agonist muscles was different for young and older adults sub 100 Hz. Experiment 2: Older adults who participated in the reduced visual feedback group exhibited greater retention and transfer of tasks than older adults who participated in the magnified visual feedback group. The oscillatory activation of the agonist muscle sub 100 Hz was associated with differences in motor learning for the two groups. We demonstrate that magnified visual feedback compromises the ability of older adults to control movements, which extends findings of force tasks. Most importantly we demonstrate that reduced visual feedback can be used as part of a low-intensity training protocol to improve motor learning in older adults.

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33.319 **Development of visual texture segregation during early childhood**

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Most of the studies that have focused on the development of the visual system in children using visual evoked potentials (VEPs) have used stimuli soliciting only one level of visual processing. However, the perception of a visual scene requires a multitude of analytical processes ranging from the encoding of various characteristics of the visual stimuli, to the processing of top-down information and finally leading to segmentation of forms and recognition of stimuli. Numerous studies have shown that this more complex visual process can be objectively studied with specific VEPs, namely texture segregation visual evoked potentials (tsPEVs). Even though it has been demonstrated that texture segregation appears in the first few months of life and that it continues to develop within the first year, it is not known at what age texture segregation processes reach maturity. The purpose of the present study was to determine, using tsVEPs and high-

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density EEG, the normal development of higher-level visual processing during early childhood. We assessed typically developing children aged 12 months (n=15), 24 months (n=14) and 36 months of age (n=15). Four different stimuli, two low-level (lines homogeneously oriented to the right or left) and two higher-level (orientation-defined checkerboard composed of 90° line gradients oriented concentrically or outwards) were presented randomly on a screen in front of the child. The tsVEP was obtained by subtracting low-level from higher-level responses. Results show significant ($p<.05$) differences between the 12 months and 36 months groups, for both amplitude and latency of the N2 component. More specifically, there is a latency reduction and amplitude gain with increasing age. Furthermore, the electrophysiological response pattern obtained at 36 months is comparable to the one observed in adults. In conclusion, our data show that there is a clear maturation of texture-segregation processes taking place between 12 and 36 months of age.

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33.320 **Genetic and Environmental Contributions to Chromatic and Luminance Contrast Sensitivity in Infant Twins**

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Introduction: The purpose of the present study was to determine the relative contribution of shared genetic and environmental factors to infants' contrast sensitivity (CS) for Chromatic and Luminance patterns, which are mediated by the parvocellular and magnocellular pathways, respectively. If CS is governed by genetics, monozygotic (Mz) twin pairs' sensitivity should be more highly correlated than dizygotic (Dz) twin pairs' performance, because Mz twins share, on average, twice as many genes than Dz twins share (100% vs. 50%). If genetics are not influential, the correlations between Mz and Dz twins should be equivalent. Methods: Thirteen Mz and 45 Dz twin pairs were tested (M age=4.6 months, SD=1.4). Zygosity was assessed by questionnaire and cheek swab samples. Using forced-choice preferential looking, contrast sensitivities were obtained for Chromatic (red/green isoluminant) and Luminance (dark/light) moving sinusoidal gratings (0.27 cpd; 4.2 Hz; cone contrasts between 2-46% randomized across ~160 trials). Structural equation modeling (SEM, Neale et al., 2003) was applied to determine which factors explain the variance in twin pairs' CS: additive genes (A), common/shared environment (C), and unique environment (E). Results: Logged CSs were entered into the SEM model with infants' age as a covariate. The best model fit for Chromatic CS included the genetic and unshared environment factors (AE model; RMSEA=0.08). Genetics accounted for 37% of the variance in this model. The best model fit for Luminance CS included shared and unshared environment factors (CE model; RMSEA=0.08). In this model, shared environment explained 52% of the variance in Luminance CS. Conclusion: These preliminary results suggest that both genetic and shared environmental factors influence early contrast sensitivity, and effects differ for the parvocellular (Chromatic CS) than magnocellular (Luminance CS) pathways.

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33.321 **Cortical representation for the categorical color perception in infants investigated by near-infrared spectroscopy**

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Many studies have reported the infants perceive color categorically (e.g. Bornstein, Kessen, & Weiskopf, 1976; Franklin & Davies, 2004). A recent study (Franklin et al., 2008) showed that the categorical color process in infants is lateralized in the visual field. The category effect was observed only when the stimuli showed in the left visual field. In the present study, we used near-infrared spectroscopy (NIRS) to investigate the lateralization of categorical color perception in infants. In the experiment, we presented two kinds of geometric figures to infants. One figures' color was alternating between green and blue at 1Hz (between category condition), and the other figures' color was alternating between two different colors of green at 1Hz (within category condition). Between- and within-category-color differences were equated in CIELab space. We measured the hemodynamic responses in bilateral temporal regions from eight 5- to 7-month-old infants by using NIRS (Hitachi ETG-4000 system). The hemodynamic responses were compared to the baseline in which figures changed in shapes, but not in colors. We hypothesized that infants would show different brain activity between two conditions. The main results were as follows: (1) the increased hemodynamic responses were observed only in the between category condition, (2) no significant difference was observed between left and right hemisphere in the between category condition. This was the first evidence showing the categorical color perception of infants by using a hemodynamic method. Our results suggest that colors in different categories are differently represented in the visual cortex in 5- to 7-month-old infants. However, we didn't observe any lateralized effect of categorical color perception reported in Franklin et al (2008). The possible explanations are that the lateralization of categorical color perception in infants is not robust and the lateralization could be restricted to certain stimuli, tasks or measures.

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33.322 **Contour integration and aging: effects of inter-element distance, distracter density, and stimulus duration**

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Contour integration - the ability to group information across space to extract contours - declines with aging (DelViva & Agostini, IOVS, 2007; Roudaia et. al., Vis.Res., 2008, 2011). Here, we examined how age-related changes in contour integration depend on inter-element distance, contour element collinearity, stimulus duration, and distracter density. In a 4AFC task, younger (mean age: 25 y.) and older (mean age: 66 y.) subjects discriminated the global orientation of spiral-shaped contours sampled with Gabor elements (λ= 0.3 deg, σ=0.11 deg, 90% contrast) and embedded in a field of randomly oriented distracter Gabors. In Experiment 1, stimuli were presented for 1s and their minimum inter-element distance was varied across blocks between 2λ and 8λ. Within each block, contour element collinearity was disrupted by the addition of 5 levels of orientation jitter, ranging from 0 - 60 deg. There was a constant age-related decline in accuracy for all inter-element distances and orientation jitter levels. Experiment 2 examined the effect of stimulus duration on the discrimination of collinear and non-collinear contours with 2λ and 6λ inter-element distances. Stimuli were blocked by contour type and were presented for 0.04 - 0.8s. Older subjects' accuracy declined more with decreasing stimulus duration than younger subjects' accuracy, however this effect varied with contour type. Experiment 3 examined the effect of increasing distracter density on discrimination of collinear contours with 3λ and 6λ inter-element distances. Both age groups showed higher accuracy for 3λ compared to 6λ contours for all distracter density levels. However, older subjects showed greater sensitivity to increasing density than younger subjects for contours with small inter-element distances. In sum, although the spatial range of contour integration does not change with age, the process is slower and less tolerant to the relative contour/distracter density.

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33.323 **A Comparison of VEP and Behavioral Responses to Global Form and Motion in Infant Macaque Monkeys**

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Adult primates easily integrate global form and motion cues to parse a visual scene, but this ability is not present at birth and slowly develops postnatally. To understand how the development of global perception might be related to postnatal changes in cortical maturation, we compared behavioral and neural responses to global form and motion stimuli in individual infant monkeys. Behavioral measures were made using two-alternative forced-choice psychophysics; neural responses were collected using visually evoked potentials (VEP). We tested infant macaque monkeys (Macaca nemestrina) between the ages of 20 and 40 weeks. Random dot kinematograms were used to establish motion coherence thresholds for both behavioral and electrophysiological measures. For the behavioral task, the animals discriminated the direction of motion of a dot field as a function of coherence; for VEP motion thresholds the same stimulus was swept from high to low coherence. Sensitivity to global form was measured as a difference in response to a structured Glass pattern (of translational, concen-

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tric, or radial configuration) and an unstructured random dipole stimulus. This difference was seen as an elevated first harmonic in the VEP, and was compared to the subject's ability to discriminate a structured Glass pattern from a patch of noise dipoles in the behavioral task. The pattern of results obtained with the VEP measures paralleled the behavioral data for both global form and global motion stimuli. Glass pattern stimuli that elicited behaviorally measurable responses also gave rise to an elevated first harmonic in the VEP. Motion sensitivity thresholds obtained by VEP closely matched those obtained psychophysically. Our behavioral results are consistent with the perceptual limitations seen previously in young monkeys. The parallel pattern of the VEP data suggests that this measure reflects the underlying cortical mechanisms required for the perception of global form and motion.

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33.324 The influence of accommodation and vergence coupling during visual development.

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Purpose: Accommodation (A) and vergence (V) responses are central to coordinating visual experience during development. Infants and young children have a narrower inter-pupillary distance and greater hyperopia than adults. Hence their A & V demands are both immature and vary rapidly with growth. The A & V motor systems are coupled in infancy. Is this coupling protective during development? Methods: Eccentric photorefraction was used to collect A & V responses simultaneously at 25Hz. Their coupling (ACA and CAC ratios) was measured by driving one system with the other open-loop (monocular viewing or a DOG target). A 2D or MA stimulus was used. The amplitudes of the A & V responses were then used to calculate the response ACA and CAC ratio for each subject. Results: Usable data were collected from 19 3-month-olds, 20 3-year-olds and 31 adults. The mean logACA ratios (pd/D) were .52(SD ±.25), .50(±.19) and .68(±.21) at these ages, and the mean logCAC ratios (D/pd) were -.89(±.27), -1.04(±.26) and -1.17(±.24). A PCA revealed 3 significant components that explained 82% of the variance and were interpreted as a reciprocal relationship between the ACA and CAC ratios, the accommodation response to the ACA stimulus and the vergence response to the CAC stimulus. ANOVA was also used to explore the ratios as a function of age. The ACA ratio in pd increased with age (p=.011), while the CAC in pd decreased (p=.002). Conclusions: Accommodative demands are typically increased in infancy and vergence demands are reduced. These data suggest that immaturities in the ACA and CAC ratios are appropriate for these demands in infancy, and that changes in the reciprocal relationship over time characterize the relative changes in demand.

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33.325 Accommodation and vergence: comparing 3-month-old infant responses to oculomotor model performance

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Oculomotor models have been developed over the past 50 years to understand the systems controlling vergence and accommodation in adult humans. The elements of these models (e.g. phasic and tonic components, plant, and cross-links) have been developed to model adult empirical behavior, but their relevance to performance during infancy is to be determined. Infant accommodation and vergence responses were measured in a full-cue binocular condition, an open-loop accommodation condition (CA/C ratio), and an open-loop vergence condition (AC/A ratio). Three-month-old infants (n = 10) watched an animated movie that was moved between dioptric positions of 1.1D and 2.85D. Responses were recorded with the PowerRefractor (Multi Channel Systems) at 25Hz. The mean change in accommodation and vergence responses was calculated for each condition. Mean amplitudes in the binocular condition for accommodation and vergence were 2.27 D and 1.57 MA. Mean CA/C and AC/A ratios for these infants were 1.63 D/MA and 0.53 MA/D. These empirical values were compared to simulations using Hung and Semmlow's static model (1980) and Schor's dynamic model (1992). The response ratios predicted by the adult parameters in each model underestimated the empirical CA/C in infants (<0.80 D/MA) and overestimated the empirical AC/A ratio in infants (>0.85 MA/D). Individual infant full cue, and open-loop empirical data could be simulated with a single set of adjusted parameters to generate mean amplitudes of 1.89 D and 1.40 MA and ratios of 1.50 D/MA and 0.62 MA/D while incorporating the individual's refractive error in addition (no significant differences were found between the two models). These models only marginally underestimated the empirical accommodation and vergence amplitudes, and the incorporated parameters are sufficient to capture the critical immaturities of the human infant.

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33.326 Infants' Visual Attention While Viewing Naturalistic Actions

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Cues such as directed gaze, facial expressions, and manual gestures provide rich information that facilitates social interactions. Using looking time methods, previous studies have found that infants prefer faces to non-face stimuli (Mondloch et al., 1999; Morton & Johnson, 1991), discriminate biological from non-biological motion (Bertenthal et al., 1987; Simion et al., 2008), and are sensitive to others' gaze and eye contact (Hood et al., 1998; Farroni et al., 2002). These, however, have been examined in isolation. Here we present a new eye tracking paradigm for dynamically studying infants' and adults' visual attention to competing social cues while viewing naturalistic action sequences, to more precisely examine how and when visual attention shifts and how this varies with age. Sixteen video stimuli (average duration = 24 sec) were produced with five female actors performing infant-directed actions (e.g., pouring into a mug, placing a bow on a box; see Figure 1). Eight- and twelve-month-old infants and adults (N = 62) were shown these videos while gaze was measured with a Tobii corneal reflection eye-tracking system. Areas of interest dynamically defined the actor's face, hands, and objects (see Figure 2). The actor's social cue events (e.g., smiling, speaking, eye contact, and reaching for, grasping, and holding the objects) were observationally coded. The data reveal strong correlations between the two groups of infants and adults, though infants' fixations lagged behind adults' by about 250ms (see Figure 3). Furthermore, infants responded to triadic relations differently than adults, and whereas12-month-old infants attend more to actions and objects, 8-month-old infants consistently attend more to the actors' faces. Additional analyses reveal adults are more sensitive to observationally coded social cues (e.g., smiling, speaking, and eye contact). These results highlight the importance of fine-grained spatiotemporal analyses and suggest development of sensitivity to social cues beyond the first year.

33.327 Developmental Changes in Infants' Visual Attention to Pointing

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Pointing and eye gaze are deictic gestures that can be used to orient the attention of another person towards some distal referent. Recent research reveals that very young infants shift their attention in response to gaze cues. The current study tested whether 4- and 6-month-old infants' also reflexively orient in the direction of a pointing hand (Figure 1). Infants were tested for 48 trials in a gaze-contingent paradigm using a Tobii eye tracking system. At the beginning of each trial, infants' gaze was attracted to the center of the screen, and then a pointing hand or foil replaced the attention-getter. After infants looked for 100 or 500 ms (SOA), a moving and sounding target appeared to the left or right of the stimulus cue. The target remained visible until localized by the infant, and then both stimulus cue and target disappeared terminating the trial. Targets were congruent with the direction of the stimulus cue on 50% of the trials. When the SOA was 500 ms, 4-month-old, but not 6-month-old, infants responded faster to the congruent target when cued by the pointing hand, but not when cued by the foil (Figures 2 and 3). Reflexive orienting by adults occurs only when the SOA is less than 500 ms; intentional orienting occurs at slower SOAs. When the SOA was 100 ms, 6-month-old infants responded faster to the congruent than to the incongruent pointing hand, but this differential response did not generalize to the foil (Figure 4). These results suggest that young infants shift their attention in the direction of a pointing hand, but that this process undergoes a developmental shift between 4 and 6 months of age.

33.328 Where do mothers point their head when they walk and where do babies point their head when they are carried?

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Gaze patterns differ by task, but how do task-relevant gaze patterns develop? We compared patterns of eye and head motion produced while mothers carried their infants down an indoor hallway. Methods. We analyzed data from (N=6) mother/infant dyads who both wore head-mounted eye trackers that provided a scene video and gaze position at 30 Hz. Eye position data series were converted into rotational pitch and yaw velocities. Head movement was calculated by extracting optic flow from recorded videos and self-motion from flow. We limited the analysis to frames where the focus of expansion (FOE) or the center of rotation (COR) were within two degrees of visual angle estimated from two methods (Heeger & Jepson, IJCV 7, 1992; Raudies & Neumann, Proceedigns DAGM, 2009). Circular distributions of the direction of FOE, COR, and center of fixation (COF) relative to the origin of the scene camera were calculated. Results. In infants, the FOE pointed upward, consistent with a downward-pointing head position. Mothers' FOEs pointed to the left and right. Babies CORs were elongated along the horizontal axis; that of mothers was elongated along the vertical axis. Mothers shifted gaze left/right more often than up/down. Correlations between flow of the scene videos from babies and their mothers were higher (~70%) than those for the eye-velocities and laminar flow (~55%), and were higher than those for eye-velocities of mothers and their babies (~40%). For mothers and babies the distance between FOE and COF spreads over a large range. Conclusions. Mothers explore the scene along the horizontal axis more so than infants. Passively carried infants experience pitch rotation and generally direct their head toward the ground.

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33.329 Words cue children's attention in a visual search task

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Word learning poses a referential problem: when a label is presented, there are potentially many objects in view, each with several different properties that may or may not be relevant to the category being learned by the child. Most theories of word learning solved this problem by proposing that children have language-specific knowledge that guides their learning. In this set of experiments, however, we explore an alternative framework: by keeping track of regularities in the environment (e.g. most object categories are organized by shape, words and shapes co-occur), the learner's attention can be rapidly cued to an object by a word. Under this attention-based account, verbal labels should show clearly measurable effects on the rapid deployment of attention in visual search. We developed a search task suitable for young children using a computer touchscreen, and tested the prediction that words can cue children's attention to the shape of the objects. In the first experiment we used a conjunction search (with half the distractors sharing the shape but not the color with the target, and vice-versa) and in the second experiment we manipulated the degree of shape similarity among target and distractors. Both experiments varied the number of distractors (2 to 12 in experiment one; 3 to 12 in experiment two). Across experiments we found a decrease in search times (the intercept but no interaction with number of distractors) when the label that designates the target object was presented. The presentation of an unrelated word ('go') did not facilitate search times, ruling out sound-related arousal effects. The results suggest that nouns rapidly cue attention to shape in 3 years-old children, providing a stepping stone to a mechanistic account of how words organize attention – and in so doing, organize early word learning.

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33.330 Prevention of Glaucoma through Exercise: A meta-analysis

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Primary Open Angle Glaucoma (POAG) is an optic neuropathy that results in the loss of visual field. Elevated intraocular pressure (IOP) is one of many risk factors for POAG. For over four decades researchers examined the relationship between exercise and reduction of IOP. POAG progresses asymptomatically over years and not all patients comply with long term drug regimes. Exercise could be an important complementary treatment but to be considered a viable early intervention for those at risk it is important to identify the most effective combination of intensity and duration. A meta-analysis was performed to compare the effect of these exercise parameters on IOP levels in a non-clinical population. Searches were conducted via PubMed and Google Scholar and 63 studies were obtained. Studies were excluded as per the requirements of the analysis or a lack of variance measures related to the mean change in IOP. The ten studies selected include sedentary or normally-active participants with normal baseline IOP (10 to 21 mmHg) who completed a single bout of mild (40% HR) to moderate (50 to 70% HR) aerobic exercise ranging from 2 to 60 minutes. There is a clear effect of exercise on the reduction of IOP ranging from 1 to 5 mmHg. Although we could not compute a global effect size because the 21 conditions did not each come from independent groups, we observe certain patterns in the results. First, the active and sedentary participants appear to benefit equally from exercise. Second, there is an almost twofold reduction in IOP from the mild to moderate intensity conditions. Finally, the duration of exercise appears to influence outcome for the mild but not moderate intensity conditions. The relationship between intensity and duration needs to be analyzed further in a longitudinal study that focuses on individuals at risk for POAG.

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33.331 Poorer face recognition in left-eye amblyopes

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Introduction: Amblyopia is the commonest cause of childhood visual impairment and has been understood as a low-level vision problem. We ask whether amblyopia has consequences for face recognition, comparing left-eye (LE) to right-eye (RE) amblyopes. The slower development of the nasal vs. the temporal hemifield pathway in infancy (Lewis and Maurer, 1992) predicts that LE deprivation should disproportionately hinder input to the developing face-processing-implicated right brain hemisphere, potentially causing a larger face processing deficit in LE than RE amblyopia. Methods: We recruited and tested 3936 participants, unselected with regard to amblyopia or face recognition ability, via our website Testmybrain.org. Participants reported whether they have or had amblyopia, and, if so, in which eye. As a measure of face recognition ability, they also took the Cambridge Face Memory Test (CFMT; Duchaine and Nakayama, 2006). Results: In all, 252 participants indicated that they have or had amblyopia. Of these, 193 indicated which eye was affected (LE=119, RE=74). LE amblyopes recognized faces more poorly than both RE amblyopes (p=0.005) and non-amblyopic controls (p=0.014). RE amblyopes recognized faces slightly, but non-significantly, better than controls (p=0.14). Conclusion: We find a face recognition deficit in LE, but not RE, amblyopia, indicating that amblyopia can impact high-level vision. The specificity of this deficit to LE amblyopia rules out current visual acuity as an explanation, since LE and RE amblyopes have similar acuity. Our work also extends the prior finding of a face perception deficit specific to LE (not RE) congenital cataract patients (LeGrand et al, 2003) to a condition, amblyopia, with less extreme visual deprivation and to a test, CFMT, that has been tied to everyday social functioning.

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33.332 The Development of Sensitivity to the Direction of Motion

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Last year (VSS 2011), we reported that, under most conditions, sensitivity to differences in direction of motion improves dramatically between 5 and 7 years of age, with a smaller improvement between age 7 and adulthood. This was true for smaller dots (diameter = 2.5 arcmin) moving relatively slowly (4.16°/s) or quickly (8.65°/s) and for larger dots (diameter = 10 arcmin) moving quickly. Surprisingly, adults performed poorly when the larger dots moved slowly—their minimum discriminable deviation from vertical (10.3°) was worse than that of 7-year-olds (4.7°) and no better than that of 5-year-olds (10.4°). We speculated that this poor performance in adults, but not 7-year-olds, might be related to the onset of inhibitory mechanisms after age 7 (e.g., Tadin et al., 2003). To estimate when these inhibitory mechanisms might become adult-like, we are using the same procedure with older children. As before, observers indicated on each 1s trial

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whether the dots moved to the left or right of a vertical reference line. We used a 3-down, 1-up staircase to measure the minimum deviation discriminated from vertical for the smaller and larger dots moving at the slower or faster speed. Sensitivity was adult-like in three of four conditions by 9 years of age (n = 20/grp; ps > 0.05). However, for the large (10 arcmin) slowly moving (4.16°/s) dots, 9-year-olds (2.8°) were significantly better than both 7-year-olds and adults (ps <0.01). Preliminary results from seven 12-year-olds and ten 15-year-olds show that thresholds begin to increase toward adult values after age 12. However, even at age 15, thresholds for the large, slow dots are still ~2.5 times better (4.2°) than those of adults (10.4°). The results suggest that inhibitory mechanisms that limit adults' performance for large, slowly moving stimuli may continue to mature throughout the teenage years.

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Face perception: Disorders

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

33.401 Recovery from achromatopsia and prosopagnosia is not reflected by corresponding changes in the response to color or faces in human visual cortex

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A 17 year old male (JJ) presented with a complete loss of vision following head trauma. Over 5 days, JJ recovered acuity, but revealed a specific deficit in color vision (achromatopsia). Structural MRI scans revealed no obvious lesion. 10 days after injury, JJ was tested with a battery of visual tests that showed: improving, but still abnormal color discrimination, normal stereopsis, normal motion discrimination and normal visual acuity. Tests of face perception showed that he also had a selective deficit in the ability to recognize familiar faces (prosopagnosia), but normal recognition for objects and places. 20 days after injury, color vision had improved, but he remained densely prosopagnosic. JJ was then tested weekly to map recovery of function. Over this period, color vision improved, but he was unable to recognize faces. Additional MRI scans failed to show any structural abnormality. 4 months after his initial loss of vision, JJ showed a sudden recovery in his perception for color and faces. Throughout his recovery, fMRI was used to measure responses in his visual cortex. JJ showed normal visual field maps, including an intact hemifield representation in V4. His responses to color in V1 and V4 showed no clear signs of change over time. We were also able to localize face-selective regions, such as the OFA, FFA and STS, which showed a normal response to facial identity. In sum, we found no changes in these functional measures of color and face processing from pre- to post-recovery. These results show that specific deficits in visual perception can exist without an identifiable lesion and in the absence of changes to conventional measures of functional response. This suggests that the responses of these regions may be necessary, but not sufficient for the normal recognition of color and faces.

33.402 The Prosopagnosic Profile of Patients Deprived of Early Vision by Bilateral Congenital Cataracts

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Previous studies indicate that patients treated for bilateral congenital cataract are later impaired in processing faces holistically (Le Grand et al., 2004) and in differentiating between faces based on the spacing between their internal features (Le Grand et al., 2001; Robbins et al., 2010). However, their face recognition abilities have never been tested formally. In this study, we compared 12 cataract-reversal patients to 24 age-matched controls with normal vision on their ability to recognize famous faces (Famous Face Task) and recently learned faces (Cambridge Face Memory Test). We also evaluated their subjective impression of their face memory (Prosopagnosic Questionnaire). Finally, we measured patients' sensitivity to the composite illusion (Composite Face Task), their sensitivity to spacing between facial features (Monkey Jane Task), as well as their ability to match unfamiliar faces presented simultaneously and with a different point of view (Benton Face Recognition Test). Overall, bilateral congenital cataract patients demonstrated a prosopagnosic-like deficit, being significantly slower and less accurate than controls in recognizing both famous faces and recently learned faces. On most questions, they also did not differ from controls in their self-reported face memory. Finally, their results at the perceptual tasks and at the questionnaire were for the most not correlated to their face recognition deficits, indicating that these measures were not good predictors of their prosopagnosia. Thus, early visual input is necessary not only for perceptual expertise in differentiating among upright faces, but also for recognizing this face category with a normal level of expertise.

Acknowledgement: NSERC (Canada)

33.403 Face Detection Deficits in Acquired Prosopagnosia

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Unlike their pronounced deficit in face individuation, prosopagnosics have been reported to not suffer a deficit in their detection of faces (de Gelder & Rouw, 2000; Rossion et al., 2003). MJH, a prosopagnosic with bilateral lesions to (what would be) FFA and OFA suffered from a fall 40 years ago but with an intact STS, expresses no subjective difficulty in face detection, suggesting that these posterior face areas do not mediate face detection. We have examined whether more rigorous testing would, however, reveal face detection deficits. When a car and a face are flashed simultaneously either left/right or above/below fixation, when instructed to look at the car, controls often cannot resist a first saccade to the face (Crouzet et al., 2010) thus incurring costs in both RTs and accuracy. These costs were not apparent with MJH who, like controls, was equally fast to faces and cars when the stimuli were shown singly, suggesting a deficit in either face detectability of their automatic engagement of attention. In a threshold experiment, we reduced the detectability of images (faces, inverted faces, or cars) by introducing phase noise (Dakin et al., 2002, Sadr & Sinha., 2004), while replacing the image's original power-spectrum with the grand mean power-spectrum of all stimuli, including faces and cars. In a two-alternative choice, two images, one a target embedded in a variable level of noise staircased to achieve 75% accuracy, and the other composed of 100% noise, were flashed simultaneously with backward masking in each trial. Compared with controls, MJH showed lower tolerance to noise, reflected in his higher detection threshold for all target categories. Nevertheless, his deficits in detecting faces (upright or inverted) were greater than with cars. MJH's lesions in bilateral occipito-temporal cortices appear to have produced a deficit not only in face identification, but also in face detection.

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33.404 Prosopagnosia Following Epilepsy Surgery: What You See Is Not All They Have

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Background: Studies of acquired prosopagnosia suggest that occipitotemporal lesions involving the fusiform gyrus are associated with perceptual deficits in face processing, while anterior temporal lesions are associated with associative or amnestic deficits, and that these lesions are right dominant. Surgical procedures for epilepsy can cause prosopagnosia in rare cases; however, the utility of their surgical lesions for structure-function correlations is uncertain, because by selection these patients have pre-operative focal neurological anomalies. Objective: We describe two cases of prosopagnosia following epilepsy surgery, in whom we located their surgical lesions and characterized their face processing networks, and related this to behavioural results in a structure-function correlation study. Method: Subjects had structural and functional MRI using a sensitive dynamic face localizer to find ROIs and characterize the status of their core face network (fusiform face area, FFA, occipital face area, OFA, and superior temporal sulcus, STS). In a perceptual battery, we evaluated face detection, face recognition, face perception, face imagery, and semantic knowledge about people. Subjects also underwent event-related potential to characterize the face-selective N170. Results: Subject R-AT1 had a right amygdalo-hippocampectomy sparing the core face network. Unlike other subjects with right anterior temporal lesions after trauma or encephalitis,

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she was impaired in face detection and perception, and had an anomalous N170 potential. Subject L-IOT1 became prosopagnosic after resection of the left fusiform gyrus and was impaired in face detection and perception. However, MRI also showed that the right fusiform gyrus was atrophic and did not show activation to faces. He was also impaired in semantic knowledge of people. Conclusion: Prosopagnosia following epilepsy surgery may reflect the effects of not only the surgical lesion but also pre-operative cerebral anomalies, resulting in more widespread functional deficits than predicted by their surgical lesion.

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33.405 **Dissociations of face and body perception in acquired prosopagnosia**

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Despite many findings showing dissociations of face and object perception, little is known about face and body perception in prosopagnosia. Here we present a systematic investigation of face and body perception in KH, a 29 year-old female who became prosopagnosic following a right amygdala-hippocampus resection. We tested KH in five perceptual experiments comparing faces and bodies: speeded detection, shape matching, feature and position matching, sex discrimination, and attractiveness rating. While KH was impaired with faces across all tasks, her performance with bodies was well-within the normal range, except for attractiveness rating. These face and body dissociations add to neurophysiological, neuroimaging, and psychophysical evidence indicating separate mechanisms for face and body perception. Moreover, despite her impaired face perception, KH showed a normal inversion effect for whole body positions but not for headless body positions. This particular finding challenges the hypothesis that the body inversion effect originates in the face perception system (Yovel et al., 2010) and suggests a further dissociation between face and head perception.

33.406 **Social perception of faces in acquired prosopagnosia**

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Facial trait perception is a crucial element of social interactions, but its relationship to other aspects of face perception such as identity and expression is unclear. Some researchers claim trait perception is by-product of mechanisms responsible for expression perception (Said, Sebe & Todorov, 2009), while others argue that trait perception is influenced by aspects unrelated to expression such as facial-width (Stirratt & Perrett, 2010) and self-resemblance (DeBruine, 2002). Here we investigate perception of trait and expression in KH, a case of acquired prosopagnosia. For trait perception we focused on trustworthiness and aggressiveness, and for expression perception we focused on happiness and anger. Our battery of tests consisted of four task formats: a sorting task modeled after the Cambridge Face Perception Test (Duchaine et al., 2007), an odd-one-out task, a categorical yes/no task, and explicit ratings. All tests were matched for difficulty and were free from floor and ceiling effects. Despite substantial impairments in identity perception, KH's perception of trustworthiness and aggressiveness is comparable to controls. Importantly, these results were robust across different test formats and different face databases (Glasgow, Karolinska, and Facegen). KH also displayed poor (but not clearly impaired) perception of happiness and anger. Our findings provide systematic evidence of intact trait perception in acquired prosopagnosia.

33.407 **CFMT-Kids: A new test of face memory for children**

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Large bodies of research focus on face processing in children and on adults with developmental prosopagnosia (DP), but little research has investigated DP in children. DP prevalence is estimated to be 2% of the population, and creates substantial difficulties for adults and children alike. A major factor limiting the study of face processing deficits in children with DP and other conditions is the lack of well-designed, reliable diagnostic face processing tests for children. As a step towards overcoming this limitation, we designed a Cambridge Face Memory Test (CFMT) for children (CFMT-Kids). This test follows the same format as the original CFMT, with 3 alternative forced-choice items that test memory for 6 target faces, but uses faces of children rather than adults. Task difficulty is calibrated for children. Data from a group of 11-year old children indicates that the test has good internal consistency (α=0.83). An 11-year-old child with DP scored 36% on the test, which is only slightly above chance and falls 2.7 standard deviations below the mean. The CFMT-Kids is available to other researchers. In addition to other tests of face perception for children, we will design a second CFMT-Kids of equal difficulty and reliability to facilitate pre- and post- training assessment in children with face perception deficits.

Acknowledgement: The Economic and Social Research Council, UK

33.408 **Don't look at the mouth, but then where? – Orthogonal task reveals latent eye avoidance behavior in subjects with high Autism Quotient scores.**

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Background. People generally look at the eyes when viewing faces, but people with autism tend to avoid the eyes. Measurements of these behavioral differences can be problematic, however, because people with high-functioning autism or Asperger's syndrome often adopt top-down behavioral strategies that mask internal tendencies. We attempt to unmask these differences in conflict situations, exploiting Laidlaw, et al.'s (VSS'11) finding that unscreened participants spontaneously look at the eyes even when their task is to avoid doing so. Method. Unscreened student participants filled out the Baron-Cohen Autism Quotient (AQ) questionnaire and viewed a series of face images (FaceGen) while their gaze was monitored (Eyelink2). There were three blocks of 48 trials, each with different instructions: don't look at the eyes ("avoid eyes"), don't look at the mouth ("avoid mouth"), or "free view". Face images had three possible expressions: neutral, happy, or disgusted. Results. Comparing subjects with high AQ (>32; N=5) vs. low AQ (<22; N=10) for the proportion of time spent looking at the eyes and the mouth, no significant differences were found in the "free view" or the "avoid eyes" conditions. However, in the "avoid mouth" condition, the high AQ group looked at the eyes significantly less than the low AQ group did (t-test, p<0.03). Regression analysis (N=27) showed the same: time spent looking at the eyes was negatively correlated with AQ scores only in the "avoid mouth" condition (p<0.04). Disgusted faces tended to elicit a bigger group difference (ANOVA, p=0.06). Discussion. Excessive top-down inhibition in the high AQ group can be a factor in the "avoid eyes" and the "free view" conditions, but not in the "avoid mouth." Whereas the "avoid eyes" may measure strength of such task-relevant control, the "avoid mouth" gets around it to isolate the purely spontaneous tendency to avoid the eyes.

Acknowledgement: JST/CREST, gCOETamagawa

33.409 **Group Difference in Feature Scanning While Learning Novel Faces**

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The scanpath used by typical individuals while looking at a familiar face is measurably different that used when they look at a novel face. It has been suggested that individuals with autism spectrum disorder (ASD) do not show such a difference. In this study we investigated the implicit timeline of novel faces becoming familiar. Twelve participants with high-functioning ASD or Asperger's (Mean age = 28.08 years, SD= 6.29) and 16 controls (Mean age = 27.44, SD = 6.76) passively viewed 17 unique images of 6 individuals and 6 houses while eye gaze information was collection via eye tracking technology. Specifically we measured changes in the number of fixations and total fixation duration within two areas of interest (eyes and mouth for faces; upper and lower feature for houses). Both groups showed evidence of learning for both faces and houses; eye gaze patterns for both groups changed systematically with increased exposures. The effect of exposures was not significantly different between groups demonstrating that the process of learning novel faces and houses was similar in both groups. Analysis of mean number of fixations and total fixation duration per exposure revealed significant group differences: the ASD participants showed no differences in eye gaze patterns for the eyes and mouth areas

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of the face in both upright and inverted faces. However, the typical group showed a focus on eyes compared to the mouth and this difference was more evident for inverted faces. There were no group differences in the effects of time and mean gaze patterns for upright or inverted houses, indicating that group differences in learning complex stimuli are specific to social stimuli. The areas of the faces that individuals focus on differed between groups and this difference was even more evident for inverted faces, for which learning is a more complex social cognitive task.

Acknowledgement: Social Sciences and Humanities Research Council

33.410 Sad benefit on self-face working memory: the effect of depression vulnerability

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The aim was to establish whether the long-term memory bias for sad faces, reported in clinically depressed patients and sub-clinical depression (dysphoria), can also be found in working memory in healthy subjects. Methods. After an experimentally-induced sadness phase, participants performed an old/new recognition task. A memory array comprising two pictures of the subject's own face and two pictures of a stranger's face was shown for 1250 ms. Each face had a positive or negative expression and it was orientated 300 right or left. After a 1500 ms retention interval, a single face was presented (probe). In half of the trials, the probe face matched one of the faces in the memory array, whereas in the remaining half, the probe was generated through a reflection about a vertical axis. The task was to compare the orientation of the probe with the orientation of the corresponding face in the memory array. Results. Participants were divided in two groups according to their scores on the Cognitive Style Questionnaire (CSQ) and their performance on the Negative-Mood Induction Procedure. Performance on the working memory task was analyzed by using signal detection measures. Highly vulnerable participants (i.e., participants with high CSQ and NMIP scores) remembered the orientation of their sad face better than either the orientation of their happy face or the orientation of a stranger's face. Less vulnerable participants exhibited no memory biases. Conclusions. A sad benefit in face working memory was obtained through negative mood induction in healthy individuals, but only in highly-vulnerable participants. The sad benefit was found for the participant's own face, but not for the face of a stranger. These findings support the cognitive theories of depression that posit a bias for negative information, particularly when it refers to the subject itself.

Face perception: Models

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

33.413 Low sensitivities but surprisingly high efficiencies for face-gender discrimination from interattribute distances

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According to an influential view, relational cues such as the distances between the main internal features of a face (i.e. mouth, eyes, eyebrows and nose) play a predominant role in face processing (Maurer et al., 2002; but see Taschereau-Dumouchel et al., 2010). Studies on face-gender perception are no exception (see Campbell et al.,1999). Nevertheless, the use of real-world interattribute distances for face-gender discrimination in humans has never been examined. This was the aim of the present study. In Exp. 1 we tested whether observers can discriminate the gender of faces based solely on real-world interattribute distances. Participants had to discriminate the gender of two androgynous faces of the same identity that were presented simultaneously on the screen: one had real-world interattribute distances of a woman and, the other, of a man. Despite relatively low sensitivities (average d'= 0.40 +/- 0.31, ranging from 0.82 to 0.05), 9 out of 11 observers performed significantly above chance (p<0.05). Surprisingly, statistical efficiencies were relatively high (M=13.91%, SD=12.85%, ranging from 37.35% to 0%). This is because real-world interattribute distances contain little face-gender information: A linear classifier trained on the interattribute distances of 250 faces (125 men) and tested on 250 novel faces (125 men) obtained a d'=1.34. Would real-world interattribute distances still contribute to gender discrimination when more informative cues such as attribute shapes and skin properties are available? In Exp. 2, we tested this by manipulating realistically the interattribute distances of 500 faces to make them more or less congruent with the gender of the face. Results showed that indeed congruency had a significant positive effect on the sensitivity (F(2.6, 44.4)=16.75, p<0.0001).

Acknowledgement: CRSNG

33.414 Congruency effects in the identification of upright versus inverted faces

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Face inversion effect is a well-established disruption of perception when viewing faces upside down. Nevertheless, observers can learn to identify inverted faces in a forced-choice setting following brief training. To investigate any qualitative differences between processes underlying recognition of upright and inverted faces we considered two hypotheses based on template matching. One possibility is that inverted faces are compared to inverted internal templates and classified based on the best match without necessarily recognizing facial identity. Alternatively, inverted faces may be first mentally rotated to upright, then matched to upright templates. To discriminate between these alternatives we measured contrast thresholds and reaction times in a task where observers briefly viewed a stimulus and selected it from a choice screen showing all alternatives. In four conditions we tested upright and inverted faces paired with choices displayed in a congruent or incongruent orientation. We hypothesized that upright faces would be recognized through the first route resulting in impaired performance in the incongruent compared to the congruent condition. In contrast, inverted faces may go through the second route predicting a reversed pattern: the incongruent condition would require one mental rotation (test) whereas the congruent condition would require two (test and choice). The results showed a main effect of orientation in both our measures with higher contrast thresholds (p=0.028) and longer reaction times (p=.044) with inverted faces. Contrast thresholds did not vary across congruency (p>.5) suggesting that inherent difficulty of the two tasks were equivalent. For both orientations reaction times in the incongruent condition were approximately 20ms longer than congruent, although this did not reach significance (p=.24). Upon closer examination we found considerable but meaningful individual differences in the reaction time data suggesting both recognition strategies might be available depending on other external factors such as degree of familiarity with the faces.

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33.415 Tolerance is tolerance of similarities: behavioral and computational evidence for a view-tolerant identity representation in face-space

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The face-space framework models face representations as locations in a multidimensional space endowed with a dissimilarity-based metric. We recently demonstrated that similarity (distance) measurements in this space under one viewpoint corresponded to similarities under another viewpoint. These data propose that tolerance of identity representations across viewing conditions can be interpreted as "tolerance of similarities". To link this notion to behavioral phenomena of view-tolerant face processing, a behavioral and a computational experiment were carried out. In the behavioral experiment, subjects rated similarities separately within each of two variants of a set of faces, differing in viewpoint either by 90o, 60o, 30o or 0o. In each condition, we constructed two face-space configurations, one for each viewpoint, and compared them. We found that these configurations were similar across different viewpoints. Interestingly, correspondence was significantly lower between configurations differing by 90o in viewpoint than between other configurations. Next, subjects performed a "same"/"different" matching task across viewpoints. Performance mirrored the different degrees of correspondence across configurations observed earlier. We further hypothesized that this tolerance of similarities could causally underlie the observed matching performance across viewpoints, if every face image was encoded as a vector of similarities to its

viewpoint-specific prototypes. To test this hypothesis, we generated faces under the previously employed viewpoints, and a computational model evaluated their similarities to arrays of randomly chosen prototypes within each view. We then simulated a matching task, with images having highly correlated patterns of similarities to viewpoint-specific prototypes judged to be the "same" face. Results indicated that the scheme was feasible and appealing, with performance decreasing with increasing magnitude of viewpoint change. Hence, tolerance may be established via within-viewpoint similarity judgments, instead of through direct comparisons across viewing conditions, which has been standardly advocated by both human and machine vision models.

33.416 **Neural theories for the recognition of dynamic faces in monkey cortex**

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Facial expressions are essentially dynamic. However, most research on faces has entirely focused on static pictures of faces. While it is clear that neurons with selectivity for dynamic facial expressions are located in the superior temporal sulcus, the underlying neural circuits and computational mechanisms are completely unknown. As a first step towards a systematic electrophysiological study of these mechanisms in monkey cortex we devised a quantitative physiologically plausible model for the processing of dynamic faces. METHODS: The model combines mechanisms from a hierarchical neural model for the norm-referenced encoding of static faces (Giese & Leopold, Neurocomputing, 2005) and different mechanisms for the integration of information over time. We tested two mechanisms: 1) 'snapshot neurons' that are selective for the temporal order of the stimuli, and 2) a completely novel mechanism that recognizes dynamic facial expressions by the detection of the temporal changes of the activity of neurons, encode faces in a norm-referenced framework. These neurons encode the distance between the actual face shape and the neutral facial expression in face space. RESULTS: Both models successfully recognize facial expressions of monkeys (e.g. coo call, or threat) from real videos, while they make fundamentally different predictions at the single-cell level. These predictions are straight-forward to test in single-cell studies. CONCLUSIONS: The proposed mechanisms are compatible with the known electrophysiological data about the encoding of dynamic faces. They result in predictions that are straight-forward to test in the context of single cell recordings: 1) sequence-selective neurons tuned to specific intermediate frames of facial movies, and 2) neurons changing their activity monotonically with the distance between stimuli and the neutral expressions in face space, and its temporal derivative. These predictions will help to structure electrophysiological experiments unraveling the cortical mechanisms of the processing of dynamic faces.

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33.417 **Comparing computer and human performance on identical face detection tasks**

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Detection of frontal faces in natural images is a well-studied problem in computer vision, with open-source and commercial solutions that achieve a high degree of accuracy. Biologically-inspired solutions to the problem have been developed. This robustness makes face detection an excellent platform for investigating the complexities of direct comparison between human and computer perceptual abilities. Here, we advance our understanding of the problem of human-computer comparison by presenting identical degraded stimuli to both human subjects and a selection of commonly used algorithms. Images are grayscale frontal face images where a face is detected 100% of the time by all detection algorithms and observers. Images are degraded by first applying a fast Fourier transform (FFT), finding mean amplitude per spatial frequency across all images, combining phase information in each image with randomized phase information at a range of coherence levels (from 10% to 90% randomization), then applying the inverse FFT to a frequency-domain signal with the average amplitudes and partially randomized phases. Neither the Haar cascade-based Viola-Jones classifiers nor two highly regarded commercial black-box classifiers assumed to work on a Haar-cascade model were able to detect any faces at coherence levels below 0.8. Human observers consistently detected faces at coherence levels of 0.6 and below. False positive and partial confidence results in human observers were qualitatively different than results with any of the classifiers tested. Importantly, it was impossible to determine whether human observers were using a holistic face detection strategy, a parts-based strategy, or were relying on non-facial image cues. While humans performed better, the uncertainty surrounding the detection method they used indicates that the perceptual function of face detection in humans cannot easily be directly compared to the function performed by computer algorithms, even when a test is devised that presents an identical challenge to both humans and computers.

33.418 **Neuro-anatomic correlates of the feature-saliency hierarchy in face processing: An fMRI-adaptation study**

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Background: Previous fMRI studies suggest that faces are represented holistically in face processing region of the human brain. However, behavioural studies have also shown that some facial features are more important or 'salient' than others for face recognition. Objective: We used fMR-adaptation to ask whether different face parts contribute different amounts to the neural signal in face responsive regions of the brain. Methods: 18 subjects first performed a same/different discrimination experiment to characterize their ability to detect changes to different face parts. Next they underwent an fMRI-adaptation study, in which limited portions of the faces were repeated or changed between alternating stimuli. Results: The behavioural study showed high efficiency in identity discrimination when the whole face, top half, or eyes changed, and low efficiency when the bottom half, nose, or mouth changed. On fMRI, there was a release of adaptation in the right fusiform face area (FFA) and right occipital face area (OFA) with changes to the whole face, top face-half, or the eyes. Changes to the bottom half, nose or mouth did not result in a significant release of adaptation. Finally, we asked whether the neural responses were more correlated with individual subjects' performance in the behavioural experiment or with physical image changes, as determined by an ideal observer technique. Adaptation in the right FFA was correlated with both perceptual and physical changes to faces, but in the right OFA was correlated only with physical properties of the image, and in the left FFA and left OFA was correlated with neither. Conclusions: The hierarchy of facial features is reflected in activity in the right FFA, further supporting the key role of this structure in our perceptual experience of faces.

Acknowledgement: American Academy of Neurology Medical Student Summer Research Scholarship, Fight for Sight Summer Student Fellowship

33.419 **A large-scale computational investigation of face space**

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What is the structure of human face space? Despite extensive work on this topic, the main qualitative properties of this space are a matter of debate and a quantitative description is still missing. Our work adopts a large-scale computational approach based on high-throughput modeling with the aim of providing a rigorous quantitative description of face space. To this end, first, we collect behavioral ratings of face similarity across a large number of stimuli and, second, we examine the structure of the space underlying human performance by means of computational modeling. Specifically, we evaluate thousands of model architectures and parameter instantiations with respect to their ability to account for the properties of human face space. Our results support three main conclusions: 1) an architecture based on independent component analysis (ICA) provides a better fit to empirical data than analogous ones based on principal component analysis (PCA) or linear discriminant analysis (LDA); 2) simple metrics (e.g. Euclidean) account better for the similarity structure of face space than complex ones (e.g. Mahalanobis); 3) color information is encoded in individual face

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representations along with luminance-based information. In addition, we find that an implementation of diagnostic component (e.g. principal component) selection improves the fits to empirical data and provides markedly smaller estimates of dimensionality. Thus, the present work fleshes out some of the main properties of human face space and, more generally, it lays out a rigorous and detailed computational approach to the study of human face recognition.

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33.420 **Applying multidimensional signal detection models of the uncertainty task: As example using face recognition**

Michael Wenger[1](michael.j.wenger@ou.edu), Robin Thomas[2], Nick Altieri[1]; [1]Department of Psychology, The University of Oklahoma, [2]Department of Psychology, Miami University of Ohio

The uncertainty paradigm has been used in vision research to evaluate whether stimulus components are processed independently, or whether dependencies exist. The paradigm consists of several experimental conditions from which sensitivity indices are estimated and combined to provide evidence for or against independence. The paradigm presents observers with a stimulus consisting of multiple components, such as a face. The values of these components differ across stimuli; for example, the size of the nose, or the distance between the eyes may differ. Observers are required to decide if the change in a component across stimuli constitutes an "increment" (i.e., the eyes are farther apart) or a "decrement" (i.e., the eyes are closer together) compared to a standard value. The task involves two conditions. In the certainty condition, the observer knows which component will contain the change. In the uncertainty condition, the component that differs from standard is unknown. Performance in each condition can be compared to that which is predicted by the independence of components. Previous applications of the uncertainty paradigm have not adequately described the foundations upon which performance indices can be understood as relating to component independence. We sought to clarify these concepts and demonstrate how to apply the results using exemplary data from a study requiring observers to make simple judgments about facial features. Specifically, we derived predictions for observer sensitivity in the uncertainty condition and implemented a relative measure of root-mean-square (RMS) that incorporates performance in both uncertainty and certainty conditions. This was carried out for three major signal-detection based decision models: a distance-classifier, an optimal decision model (ideal observer), and a decisionally separable "independent" decisions strategy. We also considered, in the context of these models, implications for sensitivity and RMS when stimulus components were perceptually correlated.

33.421 **Both low- and high-level vision factors account for visual search efficiency**

Tal Golan[1,2](golantl@gmail.com), Assaf Harel[1], Joseph DeGutis[3], Lynn Robertson[4,5], Shlomo Bentin[1,2]; [1]Deprtment of Psychology, Hebrew University of Jerusalem, [2]Center for Neural Computation, Hebrew University of Jerusalem, [3]Veterans Administration Center, Boston, [4]Department of Psychology Unniversity of California at Berkeley, [5]Veterans Administration Center, Martinez

Studies suggested that visual search for a face among non-face distracters is far more efficient than visual search for other objects. Indeed, some authors suggested that faces pop-out in such displays, perhaps because they attract attention reflexively. Other accounts for this phenomenon were suggested, based on low-level vision characteristics, which distinguish faces from objects. To address this controversy we compared the efficiency of visual search for faces, cars, butterflies, and civil airplanes among carefully chosen distracters, in typical participants, car experts and individuals with developmental prosopagnosia (DP). The search slopes for typical participants formed two clusters, one comprised of cars and butterflies (29ms and 32ms, respectively) and the other comprised of faces and airplanes (4.8ms and 11ms, respectively). Similar clusters were observed for car experts and DPs, with the following differences: For car experts the slope for searching cars was 15ms, which was faster than that for butterflies (28ms) but still slower than that for airplanes (9ms) and faces (4ms). For DPs the efficiency of visual search for airplanes, butterflies and cars was similar to typical participants. The slope for faces, however, whereas still smaller than for all other categories, it was almost twice as big (9ms) than for all other participants. Further, since none of the participants was airplane expert, we explored 8 low-vision measures that might have distinguished the airplanes from the distracters more than were other targets distinguished from the distracters, and found that, indeed, low-level factors could account for the surprising higher efficiency for searching airplanes among other objects. These data suggest that the modulation of visual search for cars in experts and faces in DP reflects the influence of high-level perceptual factors. The higher search efficiency for airplanes reflects the influence of low-level vision factors, whereas the search efficiency for faces reflects both sources.

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33.422 **Seeing sets for famous faces: power and limits of summary representations**

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Information from multiple similar objects in a set may be coded in the form of a summary statistic such as the set average (Ariely, 2001). In a series of 6 experiments we tested identity averaging for famous face sets. Participants were shown sets of four faces from different celebrities, followed by a probe face, and indicated, whether or not the a) probe image or b) identity had been presented in the set. Strikingly, participants in Experiment 1 highly frequently responded 'present' not only (correctly) when the probe had been a set item, but also (incorrectly) when the probe was an average (morph) of set identities. Previous work with faces had suggested an abstractive mechanism across unfamiliar identities (de Fockert & Wolfenstein, 2009; Haberman & Whitney, 2007), but the present results suggest abstraction of stimulus-set characteristics even in circumstances that support individuation of familiar identities. Three control studies addressed alternative explanations, including the ratio of required present responses, and potential attendance to only few exemplars during set presentation. In each case robust set averaging was observed. However, limits of the abstractive representation system were revealed in two further experiments. First, reversing the presentation order of set and probe led to better rejection of set averages during image matching. If perceptual similarity between set and probe had caused the set averaging effect in the previous experiments, no such reduction would have been expected, since similarity was exactly the same. In a final experiment, we created sets from each two male and two female faces. Set averaging occurred for within-gender averages, but was significantly reduced for across-gender averages. In conclusion, summary representations for faces seem to be formed mandatorily and in parallel to exemplar representations, given that set members belong to a common subcategory (e.g., same gender).

33.423 **Dissociations in emotion, gender, and object processing**

Pamela Pallett[1](pamela.m.pallett@dartmouth.edu), Ming Meng[1]; [1]Dartmouth College

At present, the differences between emotion, gender and object processing are not entirely clear. For example, one difference between emotion and gender processing may be a proclivity for both analytical and holistic processing with emotion, since we can ask both "Is Pam more happy or sad?" and "Is Pam happy?". We do not ask "Is Pam more male or female?". Similarly, since cars are objects, we would expect car perception to rely on analytical processing (although people rarely judge whether a car looks more like a BMW or a Honda). Previous research suggests that quantitative judgments of faces rely primarily on analytical processing – a method of encoding that is generally reserved for objects – whereas same/different judgments rely on holistic processing (Pallett et al., 2011). Here we use this technique to explore differences in emotion, gender, and object processing (i.e. cars) with both upright and inverted stimuli. Using a staircase design, we isolated individual thresholds for differences in response to "more or less" and "which is different" judgments for these stimuli. We found a main effect of task type, with greater sensitivity for "more or less" discrimination than "which is different" discrimination. Remarkably, we also found a 3-way interaction between task type, stimulus category, and upright/inverted orientation. Observers exhibited reduced sensitivity during "more or less" discrimination of inverted emotive faces, but not gender or objects. In the "which is different" task, inversion impaired the discrimination in gender and emotion, but not objects. These results suggest a dissociation between emotion, gender, and object processing, i.e., both analytical and holistic processing with emotion, holistic processing with gender, and analytical processing with objects.

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33.424 **Sex and sexual orientation differences in perceptual processing.**

Alex Giffard[1](agiffard@me.com), Caitlin Mullin[1], Jennifer Steeves[1]; [1]York University

Research has identified sex differences on a number of perceptual processing tasks where one sex outperforms the other. For instance, female participants outperform males in face processing ability, perceptual speed, and language fluency, while males outperform females on certain navigational tasks. Further, sexual orientation has been shown to have a cross-sex shift where gay men's performance resembles that of heterosexual females in lateralized cognitive tasks such as mental rotation and face recognition . We sought to confirm sex differences on a battery of perceptual processing tasks and in addition, to examine cross-sex shifts for gay men and women. We predicted that gay men will show more female typical behaviour on tasks that have previously shown sex differences. Participants performed a battery of tasks including; mental rotation, perceptual speed and accuracy, the Rod and Frame Test, the Symbol Digit Modalities Test, face recognition, mechanical and verbal reasoning, and spatial navigation, all of which have previously shown a sex difference. Participants' sexual orientation was assessed with the Kinsey scale as well as the Klein sexual orientation grid. Preliminary results suggest gay males perform in a heterosexual female typical manner on all tasks where heterosexual females outperform males including face recognition, verbal reasoning, symbol digits and perceptual speed and accuracy. Surprisingly, on perceptual tests where heterosexual males tend to outperform females including the Rod and Frame test and mental rotation, gay males perform in a heterosexual male fashion. These early findings are consistent with previous studies showing sex differences, but in addition we show that sexual orientation contributes to sex effects such that gay males consistently exhibit the dimorphic sex advantage.

33.425 **A Model of Facial Expressions of Grammar**

Carlos Fabian Benitez-Quiroz[1](benitezc@ece.osu.edu), Aleix Martinez[1]; [1]The Ohio State University

Faces convey much information about a person, including identity, gender, age, race, attractiveness and emotions. In addition, in sign languages, facial expressions are used to encode part of the grammar. It is however unknown which facial features define these facial expressions of grammar. We present a computational system that can automatically detect the shape of faces over several video sequences of signed sentences. The system then uses a functional support vector machine to determine which shape features best identify each of the grammatical rules. In particular, we consider positive and negative statements and positive and negative conditionals in American Sign Language (ASL). To this end, we use a collection of video sequences of several positive and negative conditionals and statements from nine native signers of ASL. We found that different types of 3D rotations are used to identity positive and negative statements and positive and negative conditionals. Not surprisingly headshakes are mostly associated to negation, while head nods are used in positive sentences, but other rotations of the head are also employed. The difference between conditionals and statements is in the spatio-temporal parameters of these head movements. We also identify a specific facial expression that is used by several subjects to emphasize or mark negation. The muscle activations associated to this expression are not correlated with those of any facial expression of emotion. We call this expressions the "not face." A psychophysical experiment showed that the "not face" is perceived as expressing negation even by non-signers. We also show which image shape feature are used to define the "not face" and each of the rotations of the head and define a computational model of these.

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33.426 **Holistic perception of interocular distance in synthetic faces.**

Michael Vekser[1](mvesker@yorku.ca), Hugh Wilson[1]; [1]Centre for Vision Research, York University

It has been argued that the process by which the brain accomplishes face perception is mostly holistic; that faces are perceived as a whole, rather than as a collection of separate components. The evidence for this comes from geometric differences in facial features being more accurately perceived when the whole face is presented as opposed to only some parts being shown. Our research aims to clarify the nature of holistic perception of interocular distance by using synthetic faces where we have complete control over the presence and configuration of face components. We measured subjects' thresholds for discriminating changes in the interocular distance across conditions where either the whole face was present with the eyes represented by circles, or the two circles were presented alone. We found a significantly lower($P<0.05$) threshold in the case of the whole face being presented(3.45±0.56min\` versus 4.76±0.81min\`). Next, we measured subjects' thresholds across conditions where the external features of the face (the head outline) were either present or absent. We found no significant differences($P>0.5$) in discrimination thresholds between the full face and the condition lacking the head outline(3.38±0.63min\` versus 3.20±0.58min\`). Further experiments determined the contribution of other facial features to interocular discrimination. We also used pairs of pictures with the same geometrical reference points, one of which is an abstract square-shaped face and the other a non-face abstract image. We found that when viewing the face image subjects show significantly lower($P<0.05$) discrimination thresholds than with the abstract image(3.75±0.75min\` versus 5.50±1.49min\`) despite possessing an identical set of reference points which could be used for the task. Together these results suggest that stimuli being recognized as a face provide a benefit for the purposes of discriminating face-specific features such as the interocular distance that may be distinct from the potential benefits of additional reference points.

Acknowledgement: CIHR

Object recognition: Mechanisms and models

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

33.428 **Form Perception through Phase Relations of Retina Ganglion Cell Firing and Extraocular Muscle Contractions**

Jonathan Butner[1](jonathan.butner@psych.utah.edu), Kyle Gagnon[1], Michael Geuss[1], Thomas Malloy[1], Michael Kramer[1], Jeanine Stefanucci[1]; [1]Psychology Department, College of Social and Behavioral Sciences, University of Utah

We propose a way of understanding form perception that emphasizes the changes in eye movements relative to changes in firing on the retina; a critical ratio is formed between the frequency of retina ganglion cell firing and the frequency of extraocular muscle contractions (i.e., the muscles controlling eye movements). In Experiment 1 we asked if changes in eye movement frequencies would alter perceived forms and their perceived movement by altering the critical ratio between eye movement and retinal firing frequencies. We manipulated participants' eye movements by spinning them around in a chair (Jacobson & Shepard, 2007). Participants judged whether a repeating complex dot pattern appeared the same before and after being spun. Twenty-six out of twenty-seven participants reported drastic changes in the image after being spun, suggesting the importance of eye movements in form perception. In Experiment 2, we examined whether critical ratios varied in stability for perceptions of form consistent with a phase locking formula (i.e., Farey sequence). According to the Farey sequence, the most stable ratio is 1:1, where the eye movement frequency and the retinal firing frequency are the same followed by 1:2, 1:3 and so forth following a specific hierarchy of ratios. Participants identified forms in an image, then adjusted the frames per second (fps) at which the image was displayed until they no longer saw the same form. The initial fps of the image was varied to create different critical ratios. Stability was defined as the range of fps for which participants indicated seeing the same form. The results revealed an increase in the stability of the form perceived by participants as the stability of the critical ratio also increased. Together, these experiments suggest that the perception of form is related to the critical ratio formed between retinal firing frequencies and extraocular muscle contraction frequencies.

33.429 **Small collections violate Weber's law during relative number judgments.**

Heeyoung Choo[1](h-choo@northwestern.edu), Steven Franconeri[1]; [1]Department of Psychology, Northwestern University

People can produce exact counts of small collections (1-4 objects) quickly and accurately, while for larger collections people must either create rough estimates or serially count (e.g., Trick & Pylyshyn, 1994). It is controversial whether this pattern results from Weber's law, where precision of number estimates are only precise enough to produce exact counts of small collections, or whether counts of small collections instead rely on a distinctive mechanism. We asked observers to make relative number judgments

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within both small and large collections, with equal Weber spacing within each collection. A reference collection had either 3 or 30 objects, and a target collection had 1, 2, 4, 5 or 10, 20, 40, 50 objects. Observers judged if the target had more or fewer than the reference. We tested the relative precision of number estimates for small and large collections by comparing judgments of more difficult comparisons for small collections (e.g. 2 vs. 3) with large (e.g. 20 vs. 30) collections, using easier comparisons within each collection size as a baseline (e.g., 1 vs. 3; 10 vs. 30). That is, we examined the magnitude of the 'distance effect,' where closer judgments are more difficult. According to Weber's law, as long as the ratios among these values are the same, performance should be identical. In contrast, we found that distance effects were significantly smaller for comparisons involving 1-3 than 10-30 objects. Distance effects were identical for comparisons involving larger numbers such as 3-5 and 30-50 objects. Our results suggest distinctive processing of a small set of objects in the visual system.

Acknowledgement: This work was supported by an NSF CAREER grant (S.F.) BCS-1056730.

33.430 **How independent are form and color in the ventral visual pathway?**

Jacqueline C. Snow[1](jacqueline.c.snow@gmail.com), Lars Strother[1], Alexandra C. Coros[1], Jody C. Culham[1]; [1]Brain and Mind Institute, University of Western Ontario

The human ventral visual pathway represents object shape, color and category, but the degree to which shape and color are dissociable in occipito-temporal cortex is unknown. We examined color sensitivity in shape-sensitive visual cortex and shape-sensitivity in color-sensitive visual cortex. Shape-sensitivity was measured via fMRI-adaptation (fMR-A) using objects that varied or repeated within blocks. Object images were either color photographs (shape and color) or monochrome silhouettes (shape only). Color sensitivity was measured by comparing fMRI responses to scrambled color photographs and scrambled monochrome silhouettes. Object-, face-, body- and scene-selective areas in ventro-lateral occipito-temporal cortex were functionally localized in a separate experiment, which in combination with our main experiment, enabled us to delineate a lateral 'shape stream' from a more medial 'color stream'. The streams were distinctly separable in posterior occipito-temporal cortex but overlapped in anterior ventro-temporal cortex. We found that areas of maximal overlap between these two streams did not correspond to any single category-selective cortical area. We also examined the relative sensitivity to object shape in the absence of color, to color in the absence of shape, and to the combination of shape and color. The shape stream showed consistent fMR-A to object shape throughout, but fMR-A to colored objects was highest anterior and ventral to object-selective lateral occipital cortex. The shape pathway showed a similar posterior-to-anterior trend in color sensitivity for scrambled objects, suggesting that fMR-A for colored objects was at least partly due to color adaptation in the absence of form. The color stream showed a posterior-to-anterior increase in fMR-A responses to object shape and colored photographs that was maximal where the shape and color streams overlapped. Our results demonstrate clear posterior-to-anterior changes in the relative sensitivity to shape and color, which may exhibit different degrees of neural independence at progressive stages of visual processing.

33.431 **Looking for the LOC with MEG using frequency-tagged natural objects**

Frederic Benmussa[1](turbulences55@hotmail.com), Jean-Gabriel Dornbierer[1], Stephane Buffat[2], Anne-Lise Paradis[1], Jean Lorenceau[1]; [1]CNRS-UPMC-INSERM, CRICM UMR 7225, France, [2]IRBA, Brétigny-sur-Orge, France

Previous fMRI studies found that Lateral Occipital Complex (LOC) is preferentially activated by visual objects. Here, we used frequency-tagged 3D dot scans of natural objects, and their scrambled counterparts to localize with sources reconstruction in MEG cortical regions subtending object perception as the LOC, and characterize the dynamics of their sustained MEG responses. Object tagging, consisting of Rapid Sequential Visual Presentation (RSVP) of Objects, Scrambles or mix of Objects and Scramble at 2.5hz rate was compared to feature tagging -dot renewal- with a single object at the same frequency. Localizer-defined ROIs from fMRI were also compared to, and used for, Magnetic Source Imaging. Results indicate that multiple object tagging reveals stronger activations in the temporal lobe than tagging with single object presentations. Contrasting responses to Objects and Scrambles revealed cortical sources activated between 150 and 350ms in regions comparable to those usually found with fMRI using the same –Object/Scramble- contrast. Contrasting mixture of Object and Scramble to Object or Scramble alone conditions revealed enhanced object-related activity for the mixed condition emerging around 150ms after each new stimulus onset. Cortical sources localized in the anterior temporal pole known to be involved in semantic processing were also activated. Altogether, the results indicate that frequency-tagging with MEG is well suited to uncover the localization and dynamics of perceptual processes underlying object processing.

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33.432 **ERP and EEG correlates of bottom-up and top-down image recognition in early visual areas**

Yury Petrov[1](y.petrov@neu.edu), Jiehui Qian[1], Jeffrey Nador[1]; [1]Psychology Department, Northeastern University

This study explores the effects of high-level image interpretation on responses in early visual areas. In a recent fMRI study Hsieh et al. (2010) found that the pattern of activation in early visual cortex to an identified two-tone "Mooney" image of an object was more similar to the response to its full grayscale image than to the same two-tone image when it was not identified. We report results of an analogous electrophysiological experiment: similar stimuli and experimental design were used, while evoked responses (ERPs) and spectral power responses (EEGs) were recorded. 5 images of natural objects were presented to 14 subjects in consecutive blocks: two-tone (no recognition), full-grayscale (recognition), two-tone (recognition) for each image. Each presentation consisted of 1 second image interval followed by 1 second blank screen, repeated 40 times. Central fixation was maintained. We found that, unlike fMRI, electrophysiological responses to two-tone and grayscale images were dissimilar, even after two-tone images were recognized. ERPs were almost identical between the two "Mooney" image blocks (recognition - no recognition) except for small (but significant) differences. In contrast, the grayscale block results were very different from the "Mooney" blocks results. In particular, the grayscale image ERPs were characterized by strong occipito-lateral activations 300 - 400 msec after the stimulus onset - those were missing in "Mooney" blocks. Comparing EEGs across the 3 blocks we found that image identification was accompanied by significant power increase in all frequency bands. The identification of two-tone images caused larger power increase compared to identification of grayscale images, and the time-course of EEGs was generally different between these images. We conclude that although image identification affected processing in early visual areas, the effects were quite distinct for bottom-up (grayscale) and top-down (two-tone) identifications.

33.433 **Exploring computational models of visual object perception**

Darren Seibert[1](daseibert@uh.edu), Daniel Leeds[2], John Pyles[2], Michael Tarr[2, 3]; [1]Department of Biomedical Engineering, University of Houston, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University, [3]Department of Psychology, Carnegie Mellon University

Cortical visual object perception employs a hierarchy of visual processing steps leading to the perception of complex visual features. However, the nature of these features remains unclear. One approach to this problem has been to model neural data using extant computational models of visual processing, such as Kay's application of edge filters to BOLD data in V1 (2008) or Cadieu's application of the Riesenhuber "HMAX" model (1999) to individual V4 neurons (2007). In a related vein, we have developed a downloadable toolbox to group visual object stimuli according to several pre-defined feature sets based on a variety of models drawn from computer vision. In earlier work we compared clusters derived from toolbox feature sets with those revealed through neuroimaging studies of human object perception (VSS 2011). In contrast to the models used in this work, HMAX is hierarchical, proposing translation-invariant conjunctions of oriented edges that arise as the result of multiple stages of visual processing that parallel the human ventral pathway. To better examine the efficacy of including multiple layers in object processing, we have extended the toolbox to include a modified form of the first two layers of HMAX which we then use to model the responses of individual voxels throughout the ventral stream. More specifically, we predicted voxel responses to passive viewing of real-world object stimuli based on each voxels' response to independent training-set object stimuli, and found that HMAX accurately predicts BOLD responses in human V1 and V2. This result suggests that adding further layers from HMAX may capture more anterior activity along the ventral pathway, and offer further insight into the visual features relevant to high-level visual processing.

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33.434 **Neural coding of dynamic articulating objects**

John A. Pyles[1,2](jpyles@cmu.edu), Michael J. Tarr[1,2]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology, Carnegie Mellon University

The human visual system can easily recognize objects across motion and different states of articulation. However it is still unclear how and where dynamic objects are encoded in the brain. Here we use multivariate pattern analysis (MVPA) to investigate the neural representations of dynamic objects. Subjects viewed moving, novel, articulating objects (Pyles & Grossman, 2009) in a slow event-related fMRI experiment. Two different exemplar animations of three moving objects were shown. We employed both region of interest (ROI), and whole-brain "searchlight" approaches in our MVPA. A novel localizer scan presenting moving objects and phase scrambled moving objects was used to identify brain areas selective for dynamic objects. These were found in regions similar to those for static objects, concentrated in the LOC, but also extending to more dorsal areas in the vicinity of MT complex. First, the MVPA classifier was trained on individual animations, and tested using a "leave one run out" approach. Classification accuracy was significantly above chance in the ROIs identified by the localizer. In an assumption-free analysis, a whole-brain support vector machine searchlight identified additional regions of high classification accuracy in early visual cortex focused around the occipital pole, extending dorsally to the middle occipital gyrus. Second, the MVPA classifier was trained on one exemplar of each object, but tested on the other, revealing that the majority of ROIs were not above chance classification. Again using an assumption-free method, a whole-brain searchlight analysis revealed above chance classification across exemplars in an area on the middle occipital gyrus, slightly posterior to MT complex. In contrast, early visual cortex areas were not above chance across exemplars. In sum, much of object-selective cortex is likewise recruited in the perception of dynamic objects. In addition, a dorsal area bordering on more typical object selective cortex appears recruited by moving, articulating objects.

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33.435 **Object representaion in human parietal cortex and its functional significance**

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Visual information have long been thought to be processed in two separate visual pathways, with ventral stream including regions along the temporo-occipital cortex representing object information and dorsal stream including regions along the parietal cortex representing spatial information. This view has been challenged by studies indicating the involvement of the parietal cortex in object representation. In this study, using stimuli that were controlled for low-level features, we investigated object representation in human parietal cortex and explored the functional significance of this representation in a perceptual decision making task. Observers were asked to categorize three novel object categories. The images were controlled for luminance, contrast and spatial frequency and were rendered noisy to increase task difficulty. For each observer, two noise levels were determined individually to yield behavioral performance of 100% (Easy) and 75% (Hard) correct. Using multivariate pattern analysis (MVPA), we investigated fMRI response patterns for this object classification task from five retinotopic areas along the human intra parietal sulcus (IPS 0-5). We also examined response from lateral occipital cortex (LOC), a region previously shown to be involved in processing visual object information. These regions of interests were identified individually on each observer using independent localizers. We found that it was possible to classify the three novel object categories in both the "Easy" and the "Hard" conditions, using patterns of fMRI activity from LOC, IPS 3 and IPS 4, with performance being higher in the "Easy" than in the "Hard" condition. Classification performance from IPS 0-2 did not reach significance. Thus both the object selective area LOC and sub-regions of the human parietal cortex carry visual object information that track the quality of the sensory information available for object categorization. These results suggest possible role of the human parietal cortex in object categorization and perceptual decision related processing.

33.436 **The case against normalization in fMRI pattern analysis**

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Multivariate pattern analysis of fMRI responses has become widely used in vision research. Haxby et al. (2001) introduced an influential method to investigate patterns of responses across voxels: we can correctly identify condition X if the pattern of responses to X in even runs correlates higher with the pattern of responses to X in odd runs than with the pattern of responses to another condition Y in odd runs. Before running these correlations, many researchers normalize voxel responses (separately for even and odd runs) by subtracting each voxel's mean response across conditions from its response to each condition, a step intended to remove the influence of voxel effects (e.g. higher overall responsiveness of some voxels than others). Mathematically, this step distributes variance across conditions and therefore introduces contaminating dependencies between them (i.e. normalization codes responses to each condition relatively to all other conditions). We illustrate this by running simulations in which one condition (X) is positively correlated between even and odd runs, but all other conditions (Y and Z) have a correlation of approximately zero between even and odd runs. Our simulations demonstrate that we can obtain above chance classification for all conditions after normalization. Above chance classification of both condition Y and condition Z therefore results not from information specific to either Y or Z, but rather from the absence of evidence for condition X. In many occasions, however, we want to examine whether the pattern of responses in our region of interest carries some information about X relatively to the other conditions in the study. To move beyond classification per se and quantify the relative information contained in our region of interest for one condition versus another, we should feed non-normalized data into our pattern analysis.

33.437 **Recognizing objects based on location**

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Objects often appear in predictable locations in the environment. Theoretically, this contextual information can facilitate recognition when the object is unrecognizable based on its own features, for example, under conditions of poor illumination, occlusion or peripheral viewing. Across three experiments, we assessed how location information contributes to the identification of an object whose image has been degraded (blurred), making its identity ambiguous. We also considered how location information interacts with an 'internal' object feature (color) during identification. First, subjects performed a visual search task, in which they had to determine whether a novel target object was present in a rendered 3D bedroom scene. This served to train subjects on the features and locations of the target objects. Then, subjects were briefly shown a blurred image of the scene with a single ambiguous target object within it. The subjects' task was to pick which object was in the scene from a lineup of the target objects. In Experiment 1, some of the target objects had fixed locations within the scene. We found that subjects used this location information during search and later to identify the blurred target objects. In Experiment 2, both the location and color of each object was variable but statistically predictive of the object's identity; i.e. each object appeared most often (but not always) in a particular location and was most frequently (but not always) a particular color. We found that subjects used both sources of information—color and location—equally when identifying the blurred image of the object. In Experiment 3, one property (location or color) was fixed while the other was variable. We found that fixed location was given higher priority than fixed color in identifying the object. Overall, these findings show that people use location information to identify objects when the objects' intrinsic features are ambiguous.

Acknowledgement: National Science Foundation

33.438 **Improving object classification by simultaneously learning object and contextual cues**

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Sunday AM

Numerous studies have demonstrated the use of contextual cues to improve object classification by human viewers. Inspired by human perception, a growing number of studies investigate the role of context, previously seen as clutter, for object classification. We investigate the impact of learning contextual cues while training an object classifier. Object and context features were extracted by two algorithms: Hmax (Serre et al. IEEE PAMI, 2007, 29(3):411-426) and a gist algorithm (Siagian et al. IEEE PAMI, 2007, 29(2):300-312), usually used respectively for local object classification and global scene classification. These different features were then combined into a single vector and processed by a support vector machine (SVM) for learning an object classifier. The influence of context on classification learning is studied using a new image database with 5 object classes in consistent and in random contexts (total 1,000 images). The influence of both the spatial extent of a context window around the object and the fraction of consistent contextual exemplars vs. random exemplars were analyzed. Increasing the number of consistent exemplars improved classification when objects were presented in their consistent context but penalized it when objects were in random context. A tighter contextual window was also more helpful than a wider one. Combining the features of the objects with the features of a spatially limited window around the object improved the classification compared to using object features alone (The average over the 5 object classes of true positive rate was 93% when Hmax and the gist algorithm were combined vs 82% when Hmax was used alone. These results were obtained using training and testing images that all contain objects in consistent context). Our results show quantitatively that consistent context is helpful for object classification.

Acknowledgement: DARPA

Sunday AM

33.439 A Poisson Counter Model for Visual Identification of Stimuli with Varying Contrast in Pure Accuracy Tasks

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We test a simple model of the time course of visual identification of briefly presented, mutually confusable single stimuli (Landolt's rings) with varying contrast in pure accuracy tasks. The model implies that during stimulus analysis, tentative categorizations that stimulus i belongs to category j are made at a constant Poisson rate, v(i,j). The analysis is continued until the stimulus disappears, and the overt response is based on the categorization made the greatest number of times. The model was evaluated by Monte Carlo tests of goodness of fit against observed probability distributions of responses in extensive experiments and also by quantifications of the information loss of the model compared with the observed data by use of information theoretic measures. The model provided a close fit to individual data on identification of Landolt's rings with varying contrast.

Acknowledgement: Danish Research Council

33.440 Single trial analysis of individual items across the ventral visual pathway with high-field fMRI

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Functional magnetic resonance imaging (fMRI) studies have yielded significant insights about the nature of representations across the ventral visual pathway. Amongst them is the finding of category-selective regions that respond, for example, more strongly to presentations of faces than objects. These types of comparisons, while powerful, are fundamentally limited by the need to average across presumed categories. This method yields contrasts that reflect differences in the central tendencies of the response to all of the individual exemplars with no direct measure of the actual amount of variance accounted for by the categories. Here we take advantage of the increased signal available at 7 Tesla to investigate the response to each of 768 individual stimuli presented a single time. The stimuli were drawn randomly from a commercial database, constrained only to span the entire range of image types within the database. Each stimulus was presented a single time in an event-related design. We also collected standard localizers in separate runs and identified face-, body-, word-, scene-, and object-selective regions in each participant. Even with only a single event-related trial for each image we were able to recover selectivity within these predefined regions, with individual images that contained the preferred stimulus evidencing both strong activity and grouping in the multivariate response. There was also strong correlation in the rank ordering of responses across the individual images (selectivity profile) within particular regions between participants. The design also afforded us the flexibility to compare the selectivity profiles of individual voxels across the brain in a manner analogous to traditional functional connectivity analyses. This analysis revealed both local regions and networks that shared selectivity without the need to resort to any contrast. We conclude that there is enough signal in fMRI to investigate the response to single trials, enabling far more powerful and flexible designs.

Acknowledgement: NIMH Intramural Program

33.441 Critical timing of dorsal and ventral visual streams in abrupt and ramped onset object recognition

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The dorsal and ventral visual stream dichotomy has been the subject of immense amounts of research and yet remains an area of some controversy. The ventral stream is well understood to be essential for visual perception, and object processing. The dorsal stream, however, appears more difficult to pin down. Recent models of visual processing have highlighted the role of the dorsal stream in driving bottom-up attention networks to facilitate later detailed object processing in the ventral stream. We sought to investigate the timing of necessary processing in the lateral occipital cortex (LO) in the ventral stream, extrastriate dorsal stream area V5, and the temporoparietal junction (TPJ) - a parietal area suggested to be involved in salience detection within a ventral parieto-frontal attention network, and a potential candidate for the termination point of the dorsal stream. Transcranial Magnetic Stimulation (TMS) was used to target either LO, V5, or TPJ at three latencies following visual target onset, using paired pulses with 25 ms inter-pulse intervals (providing a total range of 66 – 200 ms). Participants completed an object recognition task with two conditions: Abrupt contrast onset/offset, which was expected to tap into dorsal stream attention networks, or alternatively ramped contrast onset/offset, which was not expected to be well-suited to activating bottom-up attention networks. Whilst LO and TPJ showed a differential critical involvement for abrupt onset objects, interestingly all cortical sites showed a later critical involvement for the reduced-transience ramped onset stimuli. The temporal profile of these target sites are discussed in terms of recent models of visual processing.

Acknowledgement: Australian Research Council Discovery Project

33.442 Object recognition under little or no visibility

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How do we form perceptual decisions about objects under conditions of little or no visibility? Two explanations have been proposed. For one, random noise fluctuations in sensory regions might determine the decision. Alternatively, networks for guessing distinct from the networks active during normal object viewing might determine the choice. Here we employed multivariate pattern classification analysis of fMRI data (searchlight decoding) to investigate the encoding of perceptual decisions about objects under conditions of little or no visibility. In experiment 1, subjects discriminated between noisy images of faces, houses and cars presented for 33ms. Performance was titrated to 50% correct (33% chance level). Correct choices(and thus correctly perceived stimuli) weredecoded from bilateral occipito-temporal cortex and left parietal cortex. Incorrect choices were encoded in left occipito-temporal cortex and medial parietal cortex (all results $p<0.05$, FWE cluster-level corrected). Experiment 2 implemented the same discrimination task as experiment 1 using pictures of faces, houses and cars in 1/3 of trials. In 2/3 of the trials, however, pure Fourier-scrambled noise images with the mean amplitude spectrum of the object images were presented. Category choices for pure-noise trials were found to be encoded in bilateral occipito-temporal cortex, bilateral parietal cortex and left DLPFC ($p<0.05$, FWE cluster-level corrected). Additionally, a reverse correlation analysis of the presented noise images and the category choices on the respective trials revealed that the averaged noise images were similar to the average

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face and car images. This indicates that subjects used the extremely limited visual information to make category decisions, even on pure-noise trials. In summary, our results implicate the involvement of ventral temporal, parietal and prefrontal regions in perceptual decision making when little or no visual information is available to inform the decision process.

33.443 **Cortical surface-based meta-analysis of human visuotopic regions from published stereotaxic coordinates.**

Anthony Cate[1](acate@vt.edu), Timothy Herron[2], Xiaojian Kang[2,3], David Woods[2,3,4]; [1]Department of Psychology, Virginia Polytechnic Institute and State University, [2]Human Cognitive Neurophysiology Lab, Veterans Affairs Research Service, NCHCS, [3]Department of Neurology and Center for Neuroscience, University of California at Davis , [4]Center for Mind and Brain

INTRODUCTION: Maps of human visual cortex have become crowded with functionally-defined regions of interest (ROIs) Many of these neuroimaging ROIs overlap, in part because research groups studying different aspects of vision assign different names to similar brain regions. We applied a novel atlas-based meta-analysis to the problem of localizing published activation coordinates to cortical surface anatomy. This permitted us to quantify the distinctions and commonalities among visual ROIs from diverse lines of research (retinotopy, category specificity and control of action). METHODS: The MatLab toolbox VAMCA (Visualization And Meta-analysis on Cortical Anatomy) provides surface-based localization of cortical functional activations published as stereotaxic coordinates (nitrc.org/projects/vamca). 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. Non-parametric statistical tests are provided for determining the extent of overlap of the two groups' foci. Here we used 55,000+ systematically collected coordinates from 6 journals in the SumsDB database (sumsdb.wustl.edu/sums) as well as ROI localizer coordinates from other articles to verify how accurately a wide gamut of anatomically-labelled functional contrasts are mapped to cortex. RESULTS: Most pairs of ventral cortex ROIs were reliably distinct from each other, including FFA and the visual word form area (VWFA). However, we did find significant separation between house- vs. scene-defined versions of the parahippocampal place area (PPA). Among dorsal ROIs, we identified several cases in which ROIs from different lines of research were likely to represent the same functional region; for example the human homologs of macaque LIP, DIPSM and the saccade-defined IPS3 region. CONCLUSION: We illustrate the position of over 20 functional ROIs and the statistical reliability of their locations on the cortical surface. We hope that this meta-analysis will clarify understanding of the functional organization of human visual cortex anatomy.

Acknowledgement: Veterans Affairs Research Service

33.444 **Pre-Existing Unconscious Brain States Predict Aesthetic Judgments**

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Intuition and an assumption of basic rationality would suggest that people evaluate a stimulus on the basis of properties of the stimulus itself and any pre-existing preferences for particular stimulus attributes. However, a wide array of findings indicate that evaluations often depend not only on the thing evaluated, but also on a variety of situational factors that should not normatively bear on the evaluation. Here we demonstrate an even more radical departure from normative evaluation: Aesthetic evaluations of abstract fractal art were predicted with up to 75% accuracy (in cross-validation tests) by human subjects' brain states before the stimuli were presented. Our ability to predict aesthetic judgments was based on the pre-stimulus pattern of BOLD fMRI signals across a widely distributed network of regions in the frontal lobes. This predictive power did not simply reflect motor biases in favor of pressing one button rather than the other, and is unlikely to be influenced by trial history. Our finding indicates that endogenous unconscious neural signals that exist before trial onset can bias people's decisions when evaluating visual stimuli during aesthetic judgments.

Object recognition: Reading

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

33.447 **Dynamic dichoptic masking: luminance vs. contrast**

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Dichoptic masking was compared between luminance and contrast domains using the modified dichoptic probed-sinewave paradigm. A brief letter (16.6ms) was presented to one eye while a sinusoidally varying (luminance or contrast) masker was dichoptically presented to the other eye. The contrast detection threshold of the letter was measured at various times (phases) with respect to the flickering masks. Three flickering frequencies (1, 2, 3 Hz) and four different types of maskers were used: (1) a large uniform-field luminance-defined masker, (2) an equivalent-sized contrast-defined masker that had a 1/f power spectrum, (3) a small localized contrast masker that covered the letter area only,(4) a surround contrast masker whose area is equal area(2)-area(3). The results showed that luminance maskers generally increased the detecting threshold but not in a luminance-dependent manner. On the other hand, thresholds did vary in a contrast-dependent manner for both (2) and (3). No contrast-dependent modulation was found for (4). Our results suggest that dichoptic masking can come in at least two forms: luminance-based and contrast-based. In the former, dichoptic masking is sustained whereas in the latter it is more localized in time and space.

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33.448 **Accommodative Lag is Not Predictive of Diminished Reading Speeds in Natural Settings**

Stefanie A. Drew[1](sdrew@westernu.edu), Amy E. Escobar[1], Chris Chase[1]; [1]College of Optometry, Western University of Health Sciences

Jainta et al., IOVS 2011,11-8237, have reported that reading blurred text does not significantly affect reading comprehension, though it does result in increased reading times. These data were obtained by presenting text in an unnatural reading context, utilizing blurred sentences selected from a predetermined list. Here we investigate the effects of accommodative lag on reading speeds during a more natural reading task where text blur was caused by individual variability in accommodative function. Continuous recordings of accommodative responses were made using a WAM-5500 autorefractor for 10 minutes while participants read a passage from a children's story. Participants showed considerable variability in accommodation lag with many responding outside the depth of focus, yet reading speed was comparable across all participants and did not correlate with changes in accommodation during the 10 minute recording. These preliminary findings suggest that under natural reading conditions, individual variability in accommodative function does not affect reading speeds.

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33.449 **Weak Accommodation in Asymptomatic Young Adults**

Amy E. Escobar[1](aescobar@westernu.edu), Stefanie A. Drew[1], Chris Chase[1]; [1]College of Optometry, Western University of Health Sciences

Weak accommodative function does not always predict visual discomfort symptoms during near work (Chase C, Tosha C, Borsting E, Ridder WH. Visual discomfort and objective measures of static accommodation, Optom Vis Sci 2009;86:883-89). This study examined the possibility that individuals with weak accommodation may remain asymptomatic through a compensatory vergence response. Both binocular and monocular continuous autorefraction data was collected using a Grand-Seiko WAM-5500 autorefractor while young adults read a passage from a children's story for 10 minutes. Participants' scores on the Conlon survey (Conlon EG, Lovegrove WJ, Chekaluk E, Pattison PE. Measuring visual discomfort. Vis Cogn 1999;6:637-63) provided a measure of their visual discomfort. For some of the participants with low near work visual discomfort, accommodation lags in the monocular and binocular conditions were comparable and well within depth of focus. However, there was a subset of asymptomatic participants who exhibited a large lag outside the depth of focus in the monocular condition that decreased in the binocular condition. This may be due to a strong vergence system that compensated for weak accommodation. When they perform a binocular task such as reading in a natural setting, their vergence system affords them the ability to perform near work with relatively little discomfort even though they do not have a strong accommodative response. Objective measures of accommodation, such as autorefraction, can identify asymptomatic individuals who have weak accommodative function by comparing the accommodation lag during binocular and monocular tasks.

Acknowledgement: NIH Grant 1R15EY021021

33.450 **Both abrupt and ramped onset of contrast reversing phantom contours reveals a magnocellular impairment in dyslexia.**

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Despite thirty years of experimentation controversy still exists over whether there is a magnocellular deficit associated with developmental dyslexia and where it might operate. Thus we designed a purely magnocellular phantom contour stimuli defined by contrast reversals at high temporal frequency (58.5Hz), with the aim of comparing contrast thresholds for a 4 alternative choice orientation discrimination in a group of children (9-14 years) with dyslexia and an age- and nonverbal intelligence- matched control group. Stimuli were either abruptly presented for 4 refresh frames (34 ms), or in two reduced transience conditions via stimuli that were progressively ramped on and off over either 4 frames or 10 frames (86 ms). Children in the dyslexia group showed much higher contrast thresholds than the control group in all three conditions, thus demonstrating strong evidence for a magnocellular deficit in dyslexia. A similar relative difference in contrast threshold and similar relative difference in size of the first contrast step needed for conscious orientation discrimination was also shown by dyslexics and controls under both abrupt and ramped conditions. Furthermore although the absolute size of the differences in threshold scores between the controls and dyslexic group increased dramatically between the abrupt and the 4 and 10 frame ramped onset stimuli, a similar effect size was seen across all task conditions, suggesting a single mechanism affecting performance underlies both abrupt and ramped onset conditions. If this is true then the abrupt condition with its high transience that indicates a dorsal stream deficit in the dyslexic group gives credence to the suggestion that even when the stimuli are ramped, it is the relative ease of dorsal stream activation that limits fluency in dyslexic readers.

Acknowledgement: Australian Research Council to SGC

33.451 **Evaluating a neural shape-based framework for the emergence of visual word form representations using fMRI and the HMAX model**

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Visual word representations provide a unique opportunity to study the effect of visual training on neural selectivity throughout the ventral visual pathway. Even though it has been suggested that the processing of letter strings has inherited many of the characteristics of the processing of objects (Dehaene & Cohen, 2005, Trends in Cognitive Sciences), no computational models have been developed to generate specific neuroscientific predictions and test them empirically. Here we adapt a neural object recognition model to include case-specific and case-invariant letter string representations, resulting in the model HMAX-WORD. Population-level analyses on the responses within different layers of HMAX-WORD provide specific predictions about a progression from a representational space defined by case to a representation defined by case-invariant word identity. This case-invariant coding only occurred when high-level units in the model were tuned to letter groups and not just single letters. We compared the predictions from HMAX-WORD with data from a functional magnetic resonance imaging (fMRI) experiment on 8 participants who were shown words presented in both upper- and lower-case (e.g., 'HAAN' versus 'haan' (rooster)). The functional imaging data, analysed through multi-voxel pattern analyses, show a similar progression from case-dependent to case-invariant representational spaces as found in HMAX-WORD with units tuned for letter groups. The findings from this direct comparison of modelling and fMRI evidence confirm that word recognition is consistent with the implementation of abstract orthographic units in a feed-forward architecture. These findings reveal the potential of a combined computational and pattern analyses-based approach to understand how visual word forms are constructed in the brain and, more in general, to investigate how stimulus dimensions are represented in specific brain regions.

33.452 **Is Letter Recognition more "Ideal" than Face Recognition?**

Girish Kumar[1](girish.kumar@berkeley.edu), Gregory Wingren[1], Deyue Yu[2], Susana T.L. Chung[1]; [1]School of Optometry, University of California, Berkelely, [2]College of Optometry, The Ohio State University

Previous work (Nandy & Tjan, 2008) has shown that human observers are able to linearly integrate spatial-frequency information within letter stimuli. The purpose of this study was to determine if this ability is preserved for the task of face identification. Our stimuli consisted of 1074 standardized face images of celebrities. Stimuli were 4° in width. Each image was filtered using three different raised cosine log filters with a bandwidth of 1 octave. Two filters had center frequencies of 8 cycles/face and 32 cycles/face. These frequencies were chosen because they produced stimuli that yielded similar contrast thresholds for identification. The third filter was created by adding the first two filters. We measured contrast thresholds for identifying face images for each filter condition in seven human observers, and also for a white-noise limited ideal observer. For comparison, we measured contrast thresholds for identifying letter stimuli (x-height = 0.25°). Letters were filtered with similar filters centered at 1.35 cycles/letter and 5.4 cycles/letter as well the combination of the two. To quantify linearity, we adopted the same metric as Nandy & Tjan – the integration index, defined as the ratio between the squared contrast sensitivity of the composite and the sum of squared contrast sensitivities of component images, where a value of 1 implies linearity. For human observers, the integration index for identifying face and letter stimuli averaged 3.69±10.94 and 0.93±0.22, respectively. In comparison, ideal observer analyses yielded integration indices of 0.17±0.02 and 0.93±0.06 for faces and letters respectively. While the finding of our letter experiment replicates that of Nandy & Tjan, the results of our face identification experiment however point to a non-linear integration of spatial-frequency information. The ideal observer analysis suggests that our results could be explained by the differences in the distribution of spatial-frequency information between face and letter stimuli.

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33.453 **Writing facilitates learning to read in Chinese through reduction of holistic processing: A developmental study**

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Holistic processing has been identified as an expertise marker of face and object recognition. In contrast, the expertise marker of recognizing Chinese characters is reduced holistic processing (Hsiao & Cottrell, 2009). We have recently shown that this reduction in holistic processing is driven by Chinese writing experiences rather than reading ability (Tso, Au, & Hsiao, 2011): Chinese literates who had limited writing exposure and thus had reading performance far exceeding their writing ability perceived Chinese characters more holistically than Chinese literates who can read and write fluently, with reading performance controlled statistically in the comparison. Here we investigate the developmental trend of holistic processing in Chinese character recognition and its relationship to reading and writing abilities. As reduced holistic processing is achieved through writing experiences, we hypothesize that reduced holistic processing mediates between writing and reading abilities. We tested first, third, and fifth grade Chinese children who were learning Chinese at a public elementary school in Hong Kong that emphasized both word reading and writing abilities. We tested these kinds of abilities as well as holistic processing of Chinese character recognition using the complete composite paradigm (Gauthier & Bukach, 2007). We found that Children perceived Chinese characters more holistically than adults in our prior studies (Tso et al., 2011). This holistic processing effect was reduced as they reached higher grades. Hierarchical regression analyses showed that this reduction in holistic processing effect was driven by enhanced Chinese literacy (i.e. reading and writing accuracy) rather than age, consistent with Hsiao and Cottrell's (2009) finding. In addition, through mediation analysis, we found that writing performance predicts reading performance through reduced holistic processing as a mediator, consistent with our hypothesis. We thus argue that writing hones analytic processing, which is essential for Chinese character recognition, and in turn facilitates learning to read in Chinese.

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33.454 **One-back task functional localizer for visual word form area reveals inverse pattern of activation in readers of Russian**

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The evidence on whether there is a specialized brain area selectively responding to visually presented familiar words is highly controversial. One recent piece of evidence is provided by Wang et al. (2011) who have found greater activation for artificial versus real Chinese characters in the part of fusiform gyrus which usually manifests a greater response to words than to other types of visual stimuli (thus often considered as visual word form area, VWFA) and attributed their result to the one-back task performed by participants during the scan. We have observed similar inverse pattern of activation when contrasting familiar nouns with stimuli in unfamiliar script in readers of Russian who also performed one-back task. In 2 runs of a block-designed fMRI experiment 14 native speakers of Russian, none of whom were able to read Armenian or Chinese, viewed 25-second series of 6-character strings presented one-by-one at the center of the screen. The strings were either high frequency Russian or Armenian nouns, or words/phrases in Chinese, or consisted of identical keyboard symbols (e.g. ######). Participants raised up their thumb every time they saw two identical items in a row. When compared to any of the other three type of stimulus, Russian nouns produced higher activation in classic speech areas (left inferior frontal and superior temporal gyri), but not in fusiform gyrus. At the same time, both Armenian and Chinese stimuli produced greater bilateral mid-fusiform activation than Russian nouns. Chinese elicited slightly higher fusiform activation than Armenian, and neither type of unfamiliar writing activated the set of classic speech areas. This pattern of results suggests that the putative VWFA in fusiform gyrus may not be dedicated to stimulus-specific bottom-up processing of written words, and activity in this area may be modulated by task demands.

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33.455 **From letter features to syllables to words, without a letter stage**

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Recent studies have emphasized the importance of letters as units in word recognition (e.g. Pelli et al., 2003). However, recent findings from our lab suggest different feature extraction strategies for single letters (Fiset et al., 2008; 2009) and words (Blais et al., 2009). To explore these surprising findings further, we used a psychophysical method derived from Huey (1908). Twenty-seven observers were asked to recognize lowercase Arial letters, trigrams, 3-letter words, and 5-letter words of which only a proportion (from 1/6 to 5/6) of either the top or the bottom was visible. For each stimulus type, for both top and bottom conditions, we fitted identification performance with a Gaussian cumulative function and located the intersection of the two functions. Akin to Huey (1908; see also Blais et al., 2009), we found a clear and significant bias for the upper parts of words. Interestingly, no such effect was found for single letters (neither on average, nor taking letter frequencies into account) and trigrams (which eliminates crowding as a potential explanation). To understand the source of this upper bias and its specificity to lexical letter strings, we first submitted an ideal observer to identical tasks with added white Gaussian noise—the ideal observer was essentially unbiased. Second, we attempted to explain the upper bias for words by using human biases for each individual letters (e.g., human observers show a bias for the top part of 't'). However, we found that the individual letters' biases could not account for the words' bias—even assuming that every word is recognized solely by its most upper-biased letter is insufficient to reproduce the words' bias. Finally, we discovered a bias in human syllabic trigrams, comparable to that of words. We conclude that the visual system bypasses single letter identification on the road to word recognition.

33.456 **The perception of simplified and traditional Chinese Characters in the eye of simplified and traditional Chinese readers**

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Chinese character expertise involves reduced holistic processing and left side bias/right hemisphere lateralization (Hsiao & Cottrell, 2009). Tso, Au, and Hsiao (2011) recently showed that the reduction in holistic processing was due to writing rather than reading experience; in contrast, the left side bias depended on perceptual experience but not writing experience. Here we examined simplified and traditional Chinese readers' perception of simplified and traditional characters. Since simplified script readers do not know how to write traditional characters, they may process traditional characters more holistically than simplified characters (vice versa for traditional script readers). Both participant groups performed a character part-matching task (the complete composite paradigm) for assessing holistic processing, and a chimeric character judgment task for assessing left side bias (Hsiao & Cottrell, 2009), with three types of characters: those shared in the two scripts (Scripts-Shared), unique in the simplified script (Unique-Simplified), and unique in the traditional script (Unique-Traditional). We found that both groups perceived Scripts-Shared and Unique-Traditional characters more holistically than Unique-Simplified characters, suggesting simplified characters required more analytic processing; this effect may be due to higher visual similarity among simplified characters than traditional characters. However, no difference was found in holistic processing between the two participant groups, suggesting that their analytic character processing in one script was transferred to the processing of the other script. In addition, simplified script readers demonstrated weaker left side bias than traditional script readers in perceiving Scripts-Shared and Unique-Simplified characters, but not in perceiving Unique-Traditional characters. This effect is consistent with the recent finding that higher visual similarity among characters may lead to stronger left hemispheric lateralization/weaker left side bias (Hsiao & Cheung, 2011), and that left side bias depends on perceptual experience. In short, simplifying the traditional script leads to reduced holistic processing and weaker left side bias in the readers.

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33.457 **A right visual field advantage without left hemisphere lateralization in music notation reading**

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The divided visual field (VF) paradigm has been commonly used to examine hemispheric lateralization in the recognition of visual stimuli, i.e., a right visual field (RVF) advantage indicates left hemisphere (LH) lateralization. For example, in English word recognition, an RVF advantage has been observed in tachistoscopic recognition tasks, consistent with the fMRI finding that a region in the LH selectively responds to words in contrast to random letter strings. Recent research suggests that in addition to hemispheric lateralization, the RVF advantage may also be due to information structure of the words and reading direction (Brysbaert & Nazir, 2005). However, it is difficult to tease apart the contribution of the three factors in English word recognition. Here, we tested whether reading direction alone is sufficient to account for the RVF advantage with music reading. While music reading shares the left-to-right reading direction with English reading, music sequences are highly varied and presumably do not have an asymmetric information structure as English words. Also, experts learn to recruit both hemispheres for music reading (Wong & Gauthier, 2010), in contrast to the LH lateralization of word recognition. Music-reading experts and novices judged whether two sequentially presented three-note sequences were identical with key press. The first sequence was presented in the far-right, near-right, center, near-left or far-left part of the VF, while the central fixation of participants was monitored by eye-tracking. Experts but not novices showed a performance advantage when the sequence was presented in the RVF compared with the left VF locations. Also, faster music readers (measured by a separate perceptual fluency test) predicted a larger RVF advantage, suggesting that music-reading training results in the RVF advantage. Our results suggest that an RVF advantage does not always imply LH lateralization; reading direction alone is sufficient to account for the RVF advantage in reading.

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33.458 Reduced Crowding Accounts for Enlargement of the Visual Span After Training

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The visual span for reading is the number of text letters that can be recognized accurately without eye movements, and may be a sensory bottleneck limiting reading speed. The visual span is smaller in peripheral vision than in central vision, contributing to the slower reading speeds of people with central-field loss. The visual-span size can be enlarged through training, accompanied by an increase in reading speed (Chung, Legge & Cheung, Vision Research, 2004). Here, we report on a visual-span training experiment and decomposition analysis to determine the underlying factors responsible for the training-related enlargement of the visual span. Proposed factors include visual resolution, crowding, and mislocations (errors in the spatial order of letters). In pre- and post-tests, visual-span profiles were measured with trigrams (three horizontally-adjacent letters) displayed at eleven positions along a horizontal line at 10° in the upper or lower visual field. Letter-recognition accuracy was calculated in two ways: exact accuracy (with correct identity and spatial order) and mislocational accuracy (with correct identity regardless of spatial-order errors). An isolated-letter profile was measured with single letters to assess visual resolution. The magnitude of crowding was calculated as the difference between the isolated and mislocational profiles, and the magnitude of mislocations was the difference between the mislocational and exact profiles. Training consisted of four daily sessions of repetitive trigram visual-span measurements in the lower visual field. Consistent with previous research, we found visual-span enlargement following training, with transfer from the lower to the upper visual field. There was a substantial reduction in the magnitude of crowding and a smaller reduction for mislocations, both statistically significant. The visual-resolution profile remained unchanged. These results demonstrate that a reduction of crowding is the major factor underlying the enlargement of the peripheral visual span following training, with a minor contribution from the reduction in mislocations.

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33.459 Reduction of the lateral geniculate nucleus volume in subjects with dyslexia compared to matched controls

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Introduction Dyslexia is a prevalent reading disorder. The magnocellular hypothesis of dyslexia suggests that deficits in the magnocellular processing stream may account for some of the symptoms of the disorder. Reductions in the size of the magnocellular neurons in the human lateral geniculate nucleus (LGN) have been reported in a post-mortem study; however, the LGN has not been measured directly in living humans with dyslexia. We sought to measure the volume of the LGN in subjects with dyslexia compared to IQ-matched controls. Methods Thirteen dyslexics with measured behavioral deficits and 13 IQ-matched controls were scanned with a Siemens Trio 3T MRI scanner at the Brain Imaging Center at the University of Missouri. For each subject, 40 proton density weighted images were acquired (scanning time of one hour) with a resolution of 0.75x0.75x1 mm3. The images were interpolated to twice the resolution in each dimension then registered and averaged.The LGN were traced manually on these mean images by three independent observers who were blind to the subject's group memberships. Finally the volume between the LGN of each subject with dyslexia and the corresponding control were compared. Results The left LGN volume in subjects with dyslexia was significantly smaller than in the matched controls, approximately 20% smaller. Interestingly, no significant difference was found in the right LGN. Conclusions We have obtained measurments that are consistent with the magnocellular hypothesis of dyslexia. However, it is still unclear whether the volume reduction in the LGN of the subjects with dyslexia is restructed to the magnocellular layers or not.

33.460 Evaluation of a biologically-inspired neural network for letter recognition

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Seeking a better understanding of how we recognize letters, we compared the letter recognition performance of human subjects with that of a biologically plausible neural network (Fukushima's Neocognitron). This type of neural network, inspired by the architecture of the visual system, has been successful in OCR and natural scene classification, but so far has not been compared directly to human letter recognition. We were particularly interested in the errors made when letters were degraded, such as in the presence of noise. First, we confirmed that the network is able to recognize lower-case letters, which has not been shown before. Trained on just ten presentations of each of the 26 letters in Times font, it was robust to letter rotation (+/-45°=62% correct), spatial warping (+/-50% of character size in both dimension=75% correct), and spatial translation. Next, following the analyses of Solomon/Pelli (1994) and Chung, et al. (2002), we evaluated the model "letter channels" using stimulus filtering and filtered noise masking. Unlike the lowpass ideal observer described by Solomon/Pelli (1994), this model has a bandpass shape very similar to human observers, centered around 2-3 cycles/letter. Finally, we compared confusion matrices from new experiments, classic published results, and model predictions. After removing bias using the Luce choice model, we examined correlations between the remaining letter similarity score matrices, indicating typical confusions between letters. Correlations between the simulation and new experimental data (subjects recognizing letters in noise) were 0.62-0.7, slightly worse than agreement between observers (r=0.8-0.9). When compared to Bouma's (1971) matrix, which used a Courier font, the model trained on Times had a low correlation (r=0.32), while the Courier-trained model had a fit of r=0.64. We believe the ability of this model to capture the particular letter confusions of humans makes it a promising testbed for probing intermediate-level object recognition.

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Attention: Tracking and shifting

Sunday, May 13, 8:15 - 12:15 pm
Poster Session, Vista Ballroom

33.501 Using Eye-Tracking to Detect Vigilance

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INTRODUCTION: Today's military operational environment demands sustained attention and vigilance. Air traffic controllers, cyber operators, TSA inspectors, unmanned aerial systems operators, and satellite imagery analysts encounter lapses in attention due to the sometimes boring and monotonous nature of these positions. Mistakes in these environments can have devastating consequences. Currently, there is no tool to measure operator performance in these environments and the lapse is only noticed after a mistake is made. The purpose of this study is to determine the possible use of an eye-tracker to detect changes in vigilance performance. METHODS: Nineteen participants volunteered to participate in this study. Each participant performed a 40-minute vigilance task while wearing an eye-tracker on each of four separate days. RESULTS: Blink frequency, blink duration, PERCLOS, pupil diameter, pupil eccentricity, pupil velocity, and signal detection all had a significant change over time ($p<.05$) during the vigilance task. All of these eye metrics except pupil diameter increased as vigilance performance declined. Pupil diameter is the only oculometric that was found to decrease with performance, which has been reported in previous studies during a monotonous task. CONCLUSIONS: The results indicate that these oculometrics could be used to detect changes in vigilance. Future research is needed to assess the real-time effects of these oculometrics on vigilance performance. Using an eye-tracker in an operational environment to detect changes in sustained attention would allow preventative measures, perhaps by implementing a perceptual warning system or augmenting human cognition through non-invasive brain stimulation techniques.

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33.502 Do you know how many objects you were tracking? Evidence for enumeration errors in MOT

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Research on the limits of visual tracking abilities —typically studied with multiple object tracking (MOT) — has seen a shift, recently, from fixed-resource views to flexible-resource views. Flexible resource views have been especially successful explaining the limits of tracking computationally, in terms of specific spatial interactions between tracked and untracked objects. But all extant flexible-resource models share the assumption that while participants may not always track the right individuals (i.e. they can confuse targets and non-targets), they always track the right number of individuals. Here we show that they do not. In Experiment 1, we reduced MOT to a simple spatial working memory task: participants had to remember between three and twelve static targets among a group of identical non-targets. After a delay, they were instructed to click on all the targets and to press an 'OK' button when done. Thus the number of clicks they could provide was unconstrained. With as few as six targets, participants misperceived the number of targets on 5.3% of trials. With increasing numbers of targets, enumeration became increasingly worse, jumping to 20% with just seven targets. These results demonstrate that participants do not always select the right number of targets at the start of a trial, though flexible-resource models explicitly assume that they do. Additionally, a set of two experiments demonstrated that longer tracking durations increase enumeration errors. In other words, participants do not only confuse targets and non-targets while tracking, they may also lose targets entirely. The faithful tracking of the right number of items has been an unsupported assumption in current flexible-resource models. Further experiments explored the role of speed in enumeration. Overall, we suggest that current models must make adjustments to accommodate the fact that participants do not always know how many targets are in a display.

33.503 **Visual Task Inference in Conjunction Search Using Hidden Markov Models and Token Passing**

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The effect of visual task on the pattern and parameters of eye-movements has been long investigated in the oculomotor studies of human vision. However, there is not much done in the inverse process; that is inferring the visual task from eye-movements. Visual search is one of the main ingredients of human vision that plays an important role in our everyday life. In our previous work we developed an ergodic HMM-based model to infer the visual task in pop-out search by locating the focus of covert attention. In this paper, we improve our previous model to infer the task in a conjunction search in an eye-typing application, where users can type a character string by directing their gaze through an on-screen keyboard. In this scenario inferring the task is equivalent to figuring out what word has been eye-typed. The inherent complexity of conjunction search usually calls for off-target fixations before locating the target. However, these off-target fixations are not randomly distributed and show a pattern according to the target. The brain tends to direct the gaze on objects that are seemingly similar to the target. Therefore, we propose a tri-state HMM (TSHMM) to model the attention cognitive process of human brain, where the three states represent the fixations on the target, similar non-target and dissimilar non-target objects. We train a TSHMM for each character by using the Baum-Welch algorithm to capture the dynamics of attention during the search and construct a lexicon network by concatenating the characters and use a technique called token passing to reveal the best state sequence for the test data. The results show a great improvement compared to our previous model. We can further improve the results by setting a-priori constraints on the order of characters by making a dictionary of valid words.

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33.504 **Temporal Dynamics of Shifting Visual Attention Between Cerebral Hemispheres**

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Studies with split-brain patients have demonstrated that attention can often operate independently and in parallel in each hemisphere. However, it is still unclear whether attention shows similar hemispheric independence in healthy, intact individuals. Here, we recorded event-related potentials (ERPs) from subjects while they performed a sustained tracking task that often required them to shift attention to a different visual field during the trial. Specifically, participants attended to one of four rotating pinwheels (2 in each hemifield). Halfway through the trial, a cue prompted them to either maintain their attention at the original location, or to switch to a new location. On switch trials, the new location was either in the same hemifield as the initially tracked item, or in the opposite hemifield. The lateralized arrangement of stimuli allowed us to use the contralateral delay activity (CDA) as a neural marker of which items the participants were processing at a given moment during the trial. For between hemifield switches, we found that individuals quickly began to engage attention at the new location shortly following the switch cue onset and that this neural activity had now shifted to the opposite hemisphere (i.e., contralateral to the new location). Furthermore, by decomposing the CDA into ipsilateral and contralateral components, we found that individuals began to engage attention at the new location 200ms prior to disengaging (measured as a drop in amplitude) from the previously attended location. That is, rather than a sequential shift process of disengaging the old location before engaging the new, we found evidence that the engagement of attention to the new item preceded the complete disengagement of attention at the old location. These results provide additional support for a model of attention in which the two hemispheres can process, engage, and disengage, attention independently.

33.505 **Recently disoccluded objects are preferentially attended during multiple-object tracking**

Aysu Suben[1](aysu.suben@yale.edu), Brian Scholl[1]; [1]Dept. of Psychology, Yale University

The human visual system allows multiple featurally-identical objects to be simultaneously tracked, and the presence of periodic occlusion does little or nothing to impair this ability. However, studies of the resources that underlie this ability demonstrate the periods of momentary occlusion nevertheless demand the allocation of extra bursts of attention - the so-called "attentional high-beams effect". Here we explored how and when these resources are allocated. Across several experiments, observers tracked multiple featurally-identical objects as they moved about displays containing static occluders. At the same time, observers also had to detect small probes that appeared sporadically on the occluders, or on targets while they were in one of six states: unoccluded, about to be occluded, partially occluded, fully occluded, partially unoccluded, or just recently unoccluded. Probe detection rates for these categories were taken as indexes of the distribution of attention. (Distractors were probed just as often, so that probes did not predict target identity.) We replicated the high-beams effect: probe detection rates were higher for occluded targets than visible targets. For partially occluded targets, however, we observed an asymmetry: objects in the process of becoming disoccluded were still attentionally prioritized, but objects in the process of becoming occluded were not. This same qualitative pattern occurred for fully visible targets that were very close to occluders, with a benefit for targets that had been recently occluded, but no benefit for targets that were about to become occluded. Thus, the highbeams effect occurs not only for occluded (and thus invisible) targets but also for fully visible (but just-recently occluded) targets. This surprising result also emphasizes that the highbeams effect truly reflects a functional difference, rather than a visual difference. This effect of dynamic attention also appears to be subject to a form of inertia, but is not driven predictively.

33.506 **Multitasking Preferences, Multitasking Behaviors, and Dot Probe Detection in Multiple Object Tracking**

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The media multitasking index (MMI) measures how often people tend to consume multiple forms of media simultaneously. Previous research has shown that high media multitaskers do not filter out background information as effectively as low media multitaskers, which results in poorer performance in some laboratory tasks (Ophir, Nass, & Wagner, 2009; Cain & Mitroff, in press). Another multitasking variable of interest is one's work style preference, as measured by the multitasking preference inventory (MPI; Poposki & Oswald, 2010). Multitasking preferences and multitasking behaviors need not align, as when someone prefers to complete one task before starting another but works in an environment that demands tasks be left unfinished. This research project centers on two questions: 1) do multitasking behaviors correlate with multitasking preferences, and 2) might high media multitaskers' broader cognitive style sometimes result in improved performance for some laboratory tasks? We administered both the MMI and MPI to 583 undergraduates. We found a modest but significant correlation between the MMI and MPI, $r = .17$, $p < .01$. Interestingly, multitasking behavior (MMI) was negatively correlated with age, $r = -.09$,

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p <.05, while multitasking preference (MPI) was positively correlated with age, r = .08, p <.05. Next, we invited people whose MMI and MPI scores were in either the upper or lower quartiles to participate in a laboratory study. Participants' primary task was multiple object tracking and secondary task was probe dot detection. The dots appeared on or near a target or distractor at random times during each trial. Preliminary data indicate that, while maintaining perfect tracking performance, high multitaskers (both MMI and MPI) are better at detecting probe dots than their low multitasking counterparts. Interestingly, high multitaskers also tend to commit more false alarms, consistent with previous findings suggesting a lower threshold for filtering background noise.

33.507 Recurrence Quantification Analysis of Scan Patterns

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Recently, much research has been devoted to understanding how people look at scenes. However, there is relatively little research and analysis of the patterns of sequential fixations that occur during the time-course of scene viewing. In the present work we use categorical recurrence quantification analysis as a method for examining scan patterns (Zbilut, Giuliani & Webber, 1998; Dale & Spivey, 2005). This analysis allows for the visualization and quantification of the temporal dynamics of complex systems. Here, we apply it at the level of fixations in order to examine sequences of fixation patterns that recur (i.e. repeat) over time in a free-viewing task. In order to test the reliability of this method, we varied both the types of scenes presented (interiors, exteriors or landscapes) as well as the availability of the surrounding scene context using a gaze-contingent window. In the context-unrestricted condition, participants could see the entire scene, whereas in the gaze-contingent restricted-viewing condition, only the small portion of the scene where they were fixating was visible. When scene context was unrestricted, participants revisited previously inspected locations more often, with patterns of re-fixations occurring significantly later in the trial period. Participants also spent more time sequentially fixating local regions of the scene when viewing was unrestricted. With gaze-contingent viewing, re-fixations and sequential local scanning were rare. Relative to exteriors or landscapes, participants' scan patterns of interior scenes exhibited increased concentrated local scanning and they repeated specific sequences of fixations more frequently. Collectively these data show that categorical recurrence quantification analysis is a potentially powerful method for gaining new and reliable insights into the temporal characteristics of fixation patterns across scenes, context, and individuals.

33.508 Vision for stimuli on the hands: Evidence for an attentional boundary

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The space around our hands is perceptually distinct from the area beyond our grasp. Recent studies have shown that attention is enhanced for this space. This enhanced attentional processing manifests in slower disengagement (Abrams et al., 2008) and facilitated detection (Reed et al., 2006). These studies and others like them have shown how attention for stimuli close to the hands operates in a qualitatively different manner from attention for stimuli away from the hands. It has been argued that the space near the hands is perceptually privileged because of its potential relevance for action. In the studies presented here, we considered how attention might work for stimuli appearing on the body. These stimuli are no longer potentially relevant – they are relevant. Accordingly, we predicted that there may be qualitative differences in attentional processes for stimuli on the hands versus stimuli appearing near the hands. We present studies supporting this hypothesis. Across three experiments, we show that there is a cost to shifting attention across the body boundary. First, we show that shifting attention from near the hand to on hand – or vice versa – is very costly. In a second experiment, we show that this cost is also incurred for shifting attention from hand to hand. Finally, in an adapted flanker task, we show that incongruent flankers appearing on the body do not inhibit processing of a target appearing off the body. These results imply the existence of a new attentional boundary at the surface of the body.

33.509 PERCLOS Threshold for Drowsiness Detection during Real Driving

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PERCLOS (proportion/percentage of time in a minute that the eye is 80% closed) has been a popular topic of research for assessing driver's alertness. However, most of its validation to date was done in a simulated driving environment. In this study, we exposed drivers to monotonous 30km/hr driving in a closed road circuit for up to 4 hours. Smart Eye Anti-Sleep eye tracker system (SMART EYE AB) was used to capture drivers' eye closure throughout driving. Preliminary analysis revealed that the drivers can be classified into 3 groups. Group E (n = 11) refers to the 'elites' who lasted the full 4 hours. In Group V (n = 13) are the drivers who are vulnerable to fatigue driving and drove out of lane within 4 hours. Group U drivers (n = 14) are unmotivated drivers. For each driver, 3 PERCLOS readings were extracted: at the start of the driving as the baseline, at the point of 1-second microsleep and at end point which is upon driving out of lane or completion of the 4 hour driving. There is a significant difference between the 3 PERCLOS readings (F(2,70)=10.79, P <0.01). There is no interaction effect from grouping (F(4,70) = 1.93, P = 0.12). Pairwise comparison (Bonferroni corrected) between estimated marginal means(EMM) showed a significant PERCLOS increase from baseline (6.13%) for both 1-second microsleep and end point (P <0.01) which is 10.54% and 12.22% respectively. However, there is no significant PERCLOS difference between microsleep point and end point (P = 0.13). This study suggest PERCLOS threshold can be set at 10%, assuming critical point to be 1-second microsleep.

33.510 Training 3D-MOT improves biological motion perception in aging: evidence for transferability of training.

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In our everyday life, processing complex dynamic scenes such as crowds and traffic is of critical importance. Further, it is well documented that there is an age-related decline for complex perceptual-cognitive dynamic processes and that such processes can be trained, reversing aging effects (VSS 2011). It has been suggested that training for 3D-Multiple Object Tracking (3D-MOT) under certain conditions helps observers manage complex dynamic scenes in real life situations (Faubert & Sidebottom, 2011). Here we test this proposition by assessing whether training older observers on 3D-MOT can improve a socially relevant task such as biological motion perception. In complex scenes such as crowds, the perception of individual dynamics is important for society living. These human dynamics can be expressed by biological motion patterns. Previous research has shown that older adults require more distance in virtual space between themselves and the point-light walker to integrate biological motion information (VSS 2009). Older adults' performances dramatically decrease at a distance as far away as 4 m (in zones where it gets critical for collision avoidance), whereas younger adults' performance remains constant up to 1 m. We trained younger and older observers on the 3D MOT speed task and looked at younger and older adults' performance on biological motion task presented at 4 and 16m distance in virtual space. We also trained a control group on a visual perceptual task in the same testing conditions. Results demonstrated that, while the control group condition showed no improvements, 3D-MOT training reversed age-related biological motion perception loss where the difference found for older adults between 4 and 16 m disappeared after a few weeks of training. This demonstrates that 3D-MOT training in aging could be a good generic process for helping older observers deal with complex dynamic scenes such as when driving or navigating in dense crowds.

33.511 Perception of apparent motion in a split-brain observer.

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The ability to see motion when brief and separate views of one object occur in quick succession helps us identify pedestrians in traffic, and aids animals in spotting predators and prey. The perception of such 'apparent' motion (AM) is thought to depend on cortical connectivity to draw correspondences between the successive views. For horizontal AM across the vertical midline the corpus callosum, which connects the two hemispheres, subserves this connectivity. We tested a split-brain patient (DDC) who had received full callosectomy, providing a critical test of the role of cortical connections in AM perception. Controlling for influences of eye movements, we find that DDC cannot see horizontal AM when the direction of motion is ambiguous, indicating that the human neocortex serves an indispensable role in the resolution of perceptual ambiguities.

Acknowledgement: NWO Veni to TK, ERC to VL

33.512 Goal Objects Reduce Accuracy in Multiple Object Tracking

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Investigations of multiple object tracking (MOT) typically require participants to track a number of targets moving with random trajectories in two dimensions. These targets behave like frictionless particles trapped within a container. Though MOT has provided valuable insights about multi-focal attention (Scholl, 2009), the typical paradigm neglects a major category of natural events in which objects are set in motion by the intentional pursuit of goals. In our experiment, we altered the traditional MOT paradigm by introducing a set of airplane targets that did not bounce off of the border of their enclosure. Rather, the planes moved among discrete randomly distributed destination points. In the “destination strips” condition, these destination points were marked with landing strips, in another, “invisible destinations”, condition there were no markers, and in the “visual complexity control” condition, landing strips were visible, but planes did not move to these points. Our results showed participants were significantly less accurate at tracking when planes moved toward landing strip destinations than in either the invisible destinations condition or the visual complexity control condition. This shows that participants incur a cost to their own tracking performance that may be caused by attending to the relationship between target objects and the locations toward which these targets move. Moreover, this suggests that MOT can be influenced by the intentional relationships between targets and their movement end points.

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33.513 Effect of Occlusion and Landmarks on Single Object Tracking During Disrupted Viewing

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The ability to extrapolate the motion of objects that move in straight paths at a fixed velocity when they go behind an occluding surface has been shown to be poor but to improve when the surface has landmarks (Pylyshyn & Cohen, ARVO 1999).i Here we extend this study by having observers tap on the screen to indicate where they believe the moving object was when it was occluded vs. when visible, and when there were landmarks along the route. We also recorded eye movements to investigate whether gaze may play a role in imagined motion-tracking. Method. Forty participants tracked a square moving from left-to-right on a display screen, and twenty tracked the square moving right-to-left (during ~20 - 5 second trials for 2-occlusion and 2-landmark conditions). Subjects selected the position of tracked (but hidden) object with their finger when signaled by a randomly presented sound probe. Results. Most accurate localization occurs when object is always visible. But when occluded, gaze and touch localization undershoot actual target position regardless of movement direction or landmark presence. Response-lag is greater for gaze, except when probe onset is brief (<1.9 s) or when subjects are familiar with motion path (e.g., when block of occluding trials precede non-occluding trials.). We will discuss how lag-bias may reflect coding of object position in eye-movement system and guide imagined localization and tracking accuracy. Furthermore, we will describe an unexpected findingii, suggesting that our eyes may serve as a “place-holder” to maintain the position of tracked non-visible objects. i Pylyshyn, Z. W., & Cohen, J. (May 1999). Imagined extrapolation of uniform motion is not continuous. Paper presented at the Annual Conference of the Association for Research in Vision and Ophthalmology, Ft. Lauderdale, FL. ii Immediately following sound probe eyes tend to stay in approximate position until response is made.

33.514 Tonic and phasic influences on perceived size: Effects of visual field, stimulus eccentricity, and smooth pursuit eye movements

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Background. A tonic leftward bias exists in the perceived midpoint of horizontal lines due to the differential magnification of left hemispace by a prepotent contralateral vector of visuospatial attention by the dominant right hemisphere. Many early studies reported that visual scanning phasically modulated this tonic bias, where leftward bisection error increased with rightward scanning and vice versa. More recent studies report the opposite effect: leftward bisection error increases after execution of leftward smooth pursuit eye movements (SPEMs) and vice versa. Companion experiments found that rectangular stimuli presented ahead of an SPEM appeared larger than identical stimuli located the same distance behind the SPEM trajectory. We further explore the effect of SPEMs on size perception. Method. Stimuli were second-order isotropic blobs of Gaussian-enveloped binary noise (100% contrast; 15 comparison blobs, σ = 0.17o -0.31o; standard blob σ = 0.24o). In scanning conditions subjects smoothly tracked (7.7o/s) a target dot which moved 18.9o leftward or rightward toward the center of the display, whereupon standard and comparison blobs were presented for 50 ms to the left and right of fixation, respectively. Subjects (N = 21) judged which blob was larger. A fixed-gaze (no scan) condition was also included, such that there were three levels of scanning (leftward/rightward/none) and two levels of blob eccentricity (1o and 4o). Results. A 3 (Scanning) x 2 (Eccentricity) within-subjects ANOVA revealed a main effect of Scanning (p <.001), where scanning increased the perceived size of blobs ahead of the scan trajectory; a trend effect of Eccentricity (p = .085) where at 1o left blobs appeared larger than right blobs (reversed at 4o); and a Scanning x Eccentricity interaction (p <.001) where the magnitude of the scanning effect is largest at 4o blob eccentricity. Conclusions. Tonic visual field dependent differences in perceived size are modulated by eccentricity and SPEMs.

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33.515 Orthographic familiarity of word N affects attentional disengagement from word N-1 in reading

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The effect of the load of word N on attentional disengagement from word N-1 during reading was investigated using a dual task (adapted from Fischer, 1999; see Ghahghaei, Linnell, Fischer, Dubey, & Davis, in press). Participants were presented on each trial with a single sentence. Each sentence contained a critical word, word N, with its load manipulated at two levels of orthographic familiarity (high/low) and printed frequency (high/low). Participants (eighteen monolingual English-speakers with normal vision and reading ability) were asked to (i) read the sentence for comprehension, and (ii) make an unspeeded 2-AFC discrimination about a gaze-contingent probe. Probes were briefly (for 30 ms) superimposed on a single character at the gaze location on word N-1 after a random delay (180ms to 250 ms) from the beginning of the first fixation on word N-1. Reading was monocular and the dominant eye was recorded using a EyeLink2 eye-tracker. Each participant read 360 sentences (90 sentences for each combination of orthographic familiarity and frequency). Trials were included in the analysis if there was only one single fixation on word N-1. A two-way repeated-measures ANOVA on probe-discrimination accuracy showed an effect of the orthographic familiarity of the first trigram of word N on probe discrimination at word N-1 (p=0.01): average error for low-orthography words was 25.8 % (SEM=2.3) and for high was 18.6 % (SEM=2.5). Our result suggests that the orthographic familiarity of the first trigram of word N (a) is analysed before the word is fixated (White, Liversedge, 2006) and (b) affects the strength of attentional disengagement from word N-1.

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33.516 Maintaining selection of multiple moving objects

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Many visual tasks seem to require that we split our ‘spotlight’ of selection across multiple objects. When objects move, maintaining selection requires that each region of selection track the object in a corresponding way, an ability typically studied using “Multiple Object Tracking” tasks. We recently advanced an account of MOT performance where performance limits in moving displays can be traced back to resource limits common between both moving and static displays. These limits, including object crowding and surround suppression, are both worsened by tighter object spacing. In contrast, others have argued that there must be additional processing resources specific to moving displays, because moving objects at faster speeds decreases the number of objects than can be tracked. Such results point to a draw on some other global tracking ‘resource’ within moving displays and imply a more complex architecture underlying MOT. We argue

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that these results can be explained by the limit of object spacing - faster objects experience more instances of tighter object spacing, which lowers performance. We control for this confound by playing tracking animations in either 'slow motion' or 'fast forward', keeping the distribution of object spacing identical, while drastically changing object speed. The data show that while increased object speed impairs performance, and tracking more targets impairs performance, these factors do not interact, showing that these impairments are not due to a shared processing resource. Experiment 1 demonstrates this effect using 'random repulsion' style displays, and Experiment 2 uses 'orbiting moon' displays. We argue that performance limits in MOT tasks can be parsimoniously explained by competition for limited representational space within a map of the visual field.

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33.517 **Do the two cerebral hemispheres act as independent tracking mechanisms?**

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Information in each visual field is initially processed in visual areas located in the contralateral hemisphere. This segregation of information between the two hemispheres quickly gives way to integrated representations that result from the rapid sharing of information across the corpus callosum. An exception to this integration process is provided by split brain patients who have had their corpus callosum severed to control the spread of epileptic seizures from one hemisphere to the other. Remarkably, this operation results in superior performance of split-brain patients compared to controls on several visual tasks. For example, patients are able to search for targets in the two visual fields simultaneously resulting in a doubling of search speed compared to controls. In contrast, presenting bilateral displays to normal observers generally results in an advantage relative to unilateral presentation but one that is considerably less than the doubling of performance seen in split-brain patients. An exception to this rule was reported by Alvarez, & Cavanagh (2005) who found that bilateral presentation in a multiple object tracking task (MOT) allowed observers to track twice as many objects relative to unilateral presentation. They suggested that the two cerebral hemispheres acted as independent object tracking systems in MOT. We attempted to replicate this result in four different experiments but in all cases, we found a bilateral advantage that fell well short of the doubling of performance predicted by independent tracking systems. It appears that MOT, like other tasks such as visual search, and visual short-term memory, shows a bilateral advantage that falls short of hemispheric independence.

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33.518 **Spacing and set size effects in MOT may reflect different underlying mechanisms.**

Annie Tran[1](atran@udel.edu), Mandy Skoranski[1], Sarah Wells[1], James Hoffman[1]; [1]University of Delaware

The multiple object tracking task (MOT), introduced by Pylyshyn and Storm (1988), requires observers to track a small number of moving objects embedded in identical moving distractors. Increasing the number of objects to be tracked (set size), as well as their proximity to distractors, reduces tracking accuracy during MOT. The effects of these two variables may reflect a common underlying mechanism in which increases in set size or proximity of targets and distractors requires increases in attention to maintain accurate tracking performance (Alvarez and Franconeri, 2007). Event-related brain potentials (ERPs) provide a useful window on the putative role of attention in MOT. For example, Drew and Vogel (2008) found that MOT elicited a sustained negativity over posterior electrode sites that increased in amplitude with increases in set size, up to the maximum number of objects each observer could track. According to a single mechanism account, one might expect that decreasing spacing between objects would have similar effects on the CDA since reduced spacing, like set size, would require increased allocation of attention to maintain performance. We examined this by varying both set size and minimum inter-object spacing in an MOT task. We found that increasing set size from 1 to 2 objects increased CDA amplitude over contralateral posterior sites, replicating the results of Drew and Vogel (2008). However, decreasing spacing reduced CDA amplitude over both hemispheres. A follow-up experiment using confidence judgments replicated these results and ruled out increased guessing as a cause of these effects. These results suggest that spacing and set size effects on MOT accuracy may reflect different underlying mechanisms.

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33.519 **People are sensitive to distractor motion in multiple object tracking**

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When we track moving objects there are often distracting objects moving among our targets. Previous research leaves open the question whether distractor information is processed during tracking. Although distractors are irrelevant to the tracking task, processing some information about them, such as motion, may prevent distractors from being confused as targets. Our prior research with textured objects suggests that people use motion information to help them track targets (St. Clair, Huff, & Seiffert, 2010, JOV). Tracking objects was worse when the motion of the texture conflicted with the motion of the objects. If distractor motion is used, tracking should be affected by the motion of textures on distractors, regardless of the motion of textures on targets. Observers tracked 3 of 10 textured squares moving linearly and independently in a textured area. The texture in each square moved two times the square's speed either forward, in the same direction as the square, or, backward, in the opposite direction of the square. Texture direction was assigned to targets and distractors independently for a total of four conditions: 1) all squares had forward texture, 2) all squares had backward texture 3) targets had forward texture and distractors had backward texture, and 4) targets had backward texture and distractors had forward texture. Tracking accuracy was higher when targets had forward texture (mean proportion correct M = .79) than when they had backward texture (M = .61; $t(18) = 11.13$, $p<.01$), replicating our previous work showing target motion is used during tracking. Similarly, tracking accuracy was higher when distractors had forward texture (M = .72) than when they had backward texture, (M = .68; $t(18) = 3.98$, $p<.01$). This suggests that people are sensitive to distractor motion during tracking.

Attention: Spatial II

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

33.521 **Spatial Cueing of Infants' Target Selection and Eye Movements**

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In order to overcome our limited amount of attentional resources, particular items in space must be selected as targets. For infants, attentional resources are even more limited. Models of attention have proposed that resources are restricted to particular spatial locations, enhancing processing at these locations. Evidence for selection due to spatial attention has been provided by studies that use a spatial cueing paradigm, in which attending to the particular location indicated by a preceding cue results in faster and more accurate selection of, and eye movements to, items presented at that location compared to when no cue is presented. Whether infants exhibit similar spatial attention and target selection mechanisms has yet to examined. To this end, in the current study, 3-month-old infants were presented with either no cue or with a 150 msec cue to either the right or left of fixation indicating the subsequent location of the target to which they should make an eye movement. Then, either one stimulus or two stimuli were presented at 5° from fixation and the latency of infants' eye movements was measured to the one of the stimuli or to the cued target. Preliminary results have indicated that, consistent to findings with adults, presentation of the spatial cue resulted in a facilitation of target selection as exhibited by a decrease in infants' eye movement latency. Infants' eye movement latencies, however, were much slower than typically found in studies with adults. This finding suggests that the mechanisms responsible for the allocation of spatial attention in guiding target selection is functioning in early infancy. Yet, these mechanisms require further development to reach full efficacy, though the full extent of the developmental deficiencies remains to be determined.

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33.522 Single-pulse TMS on the FEF area induces a "narrow" focus of attention

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The role of spatial attention has often been represented as a fixed "spotlight", which highlights a specific region in the visual space disregarding other locations. However, the focus of attention can also be adjusted in size, like a "zoom-lens", according to the task demand. Although neuroimaging data supported this hypothesis, showing that the increasing size of the attended region causes an increased retinotopic extent of activation in striate and extra-striate visual areas, the causal role of fronto-parietal network in this focus size-dependent modulation in visual cortex has not been clarified. In the present study participants were asked to detect as fast as possible a visual target, which could appear at three possible eccentricities from the fixation. A non-informative cue was used to modulate the size of the attended region. In a half of the trials, a small circle cue, which included only the first eccentricity, was used to narrow the attentional focus (zoom-in). In the other half, a large circle cue, which included all the three possible eccentricities, had the role to induce participants to broaden the attended region (zoom-out). Single-pulse transcranial magnetic stimulation (TMS) on the right and left FEF areas or Vertex was used to interfere with the focus size-dependent modulation. Results show that only TMS over the right FEF area was able to interfere with the modulation of the attentional focus size. Precisely, when TMS was delivered after the onset of a large cue, participants failed to zoom-out the focus of attention. The process of zoom-in, instead, was not inhibited by TMS on the right FEF. Our results provide causal link between the role of the right FEF area and the modulation of the attentional resources allocated in the visual field.

33.523 Go Your Own Way: IOR Effects in a Social Free-Choice Task.

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Inhibition of return (IOR) refers to the finding that longer reaction times (RTs) are observed for movements made to the same location as a previous event/response (Posner & Cohen, 1984). IOR has been shown to occur both when participants perform the task on their own (individual-IOR) and in joint action contexts (social-IOR) (Welsh et al., 2005). Typical social-IOR paradigms involve participants moving to targets to the left or right of a home position. Target locations are indicated by the onset of a visual stimulus and pairs of individuals take turns responding to the illuminated location. The longer RTs to targets presented at the same location as the partner's previous response is characteristic of IOR and, as such, social-IOR has been suggested to be caused by an inhibitory mechanism enacted to bias visual search to new locations. In the present study, we sought to determine if the partner's responses also bias the individual's response selection. Pairs of participants (n=16) completed two social movement tasks in which they alternatively moved to one of two locations. In the forced-choice task, the onset of a light indicated the target for the trial. In the free-choice task, there was no light stimulus and participants were free to choose to move to either location. The analysis of the forced-choice task revealed that RTs for different targets were significantly shorter than those for repeated targets (social-IOR). Although there were no RT differences in the free-choice task, participants were significantly less likely to move to the same location that their partner just moved to (i.e., they were more likely to move to the opposite location). These results suggest that the inhibitory mechanisms underlying social-IOR can bias response selection and suggest that social-IOR is not due to attentional biases induced by peripheral visual events.

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33.524 To the end! Distribution of attention along a tool in peri- and extrapersonal space

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Tools extend our functional capabilities from peripersonal to extrapersonal space. Researchers debate whether attention is distributed along the tool or to its end and whether tools affect attention similarly in both spaces. We investigated this issue using a handheld tool with a cup at its middle and end. Participants held the tool in their right hand over a flat monitor. They performed a 50/50 go/nogo task with target locations next to each cup. In Experiment 1, groups performed the task either in peripersonal (near the body; tool held horizontally) or extrapersonal space (beyond arms' reach; tool held straight). If attention goes to the end of the tool, faster RTs were predicted for targets near the tool's end; if attention is distributed along the tool, then RTs would be similar at both target locations. Regardless of space, faster RTs were found for targets near the tool's end. Faster RTs were also found for peripersonal space overall, but no interaction. In Experiment 2, participants used the middle of the tool in a hockey-like game prior to the task to determine whether functional interaction changed attentional distribution. Faster RTs were found to targets at tool's end, and in peripersonal space. A tool part X space interaction suggested that functional interaction reduced performance differences between tool parts but only in peripersonal space. Study results indicate that attention is naturally drawn to the end of the tool but that functional tool use can redistribute attention. Functional interactions with a tool in peripersonal space integrate multisensory inputs to more evenly distribute attention between a tool's mechanical (i.e., its ability to extend reach) and functional advantages (i.e., middle tool part). For tool use in extrapersonal space, functional interaction did not affect attention, suggesting that tool use does not fully extend it from peripersonal to extrapersonal space.

33.525 More & Most: spatial vision affects word understandings on an iPad

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What, if any, are the rules governing how vision interfaces with distantly related cognitive systems? We investigated a possible relationship between visual grouping mechanisms and expectations for words like "more" and "most". We walked up to strangers on the street (N=100), gave them an iPad, and asked them to create a picture depicting an English sentence that we would say to them. We created a program for the iPad that allowed subjects to use their fingers to create any number of yellow and blue dots and place them around the screen wherever they liked. The program stored the position and color of every dot placed by the subjects. Half of the subjects were asked to create a scene in which "most of the dots are blue". The other half was asked to create a scene in which "there are more blue dots than yellow dots". All subjects were native English speakers. Notice that these two sentences will agree with one another when there are only 2 colors present (i.e., #blue > #yellow). But, these sentences may interface with vision in distinct ways as "most" seems to highlight the relationship of the "blues" to all of the dots, while "more" seems to highlight the separate groups of "yellow" and "blue" dots. Results were consistent with this hypothesis as subjects asked about "more" created images where the centroids of the yellow and blue groups were distantly separated and their alpha shapes were less overlapping than subjects asked about "most". Because these word meaning do not specifically highlight spatial relations as part of their meanings, these effects appear to emerge from grouping mechanisms in spatial vision interacting with linguistic understandings of the relevant sets for each sentence.

33.526 Ensemble statistics and attentional selection

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Here we investigated how ensemble statistics of a visual scene guides attentional selection and vice versa. Participants detected a target while extracting mean sizes of multiple sets of circles. On each trial, four sets of 5 differently sized circles (distinguished by color) were presented for 1000 ms, followed by a blank screen in which a target could appear on a centroid of one of the four sets in one third of the trials. After the blank screen, two color probes appeared to indicate two to-be-compared subsets for mean size comparison. When the target was presented on the blank screen, participants were asked to detect the target as soon as possible before they compared mean size of the two probed subsets. One of three different types

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of mean size task was assigned to each participant as a between-subject variable: participants were to judge which of two probed color-sets had larger mean size or smaller mean size, or for other participants the two tasks were intermixed and post-cued trial-by-trial. We found that participants were the most accurate in judgment of mean size when they compared the two largest color-sets in mean size, except when the task type was to choose smaller set. For the detection task, participants whose task was either to select larger mean size or randomly intermixed each trial were generally faster at detecting a target than those who selected smaller mean size. In addition, when the task was to choose larger mean size, participants' reaction time was the fastest when the target appeared on the centroid of the set with the largest mean size. Together, these results suggest that attentional task setting influences the extraction of mean size and mean size representation guides spatial attention to the set with the largest mean size in turn without this setting.

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33.527 Selection Modulated by Inter-Trial Discriminability: Robust Reversals of Perceptual Load Effects

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Perceptual Load theory's chief hypothesis proposes that easy tasks (low-load) curb efficient selection of targets, whereas difficult tasks (high-load) allow for efficient selection. In its flagship experiment (Lavie, 1995) low-load displays comprised a single-letter target and a single-letter distractor. Low-load trials (defined by fast RTs) elicited poor target selection. In high-load blocks, targets were embedded within a string of six letters. The task became difficult and selection improved. We propose that load has been confounded with target-distractor discriminability: in high-load blocks targets could be easily distinguished from distractors because the target was always within a large string of letters, whereas the distractor was always a single letter. Such discriminability was absent in low-load blocks, where targets and distractors shared the same size. Experiment 1 (Figure 1) comprised a low-load replication compared to four low-load conditions where distractors could be discriminated by four different patterns; a huge distractor, a 5-letters distractor, a different-color distractor and a distractor whose position relative to the target was fixed along each block. Load effects were reversed in all non-replicant conditions: selection drastically improved while load levels dropped even lower than the replication (Figure 2). In experiment 2, a high-load replication was compared to a high-load condition where targets and distractors shared the same size. Load predictions were reversed: the non-replicant condition resulted in deteriorated selection while load was higher than the replication. Experiment 3 comprised medium-load and low-load conditions. Selection was modulated by discriminability levels, irrespective of load levels. Contradicting the perceptual load hypothesis, nine independent conditions converged into a robust positive correlation between load and distractors' interferences (Figure 3). By manipulating discriminability, the correlation between load and efficiency of selection was propelled and reversed. Therefore, previously observed relationships between task difficulty and selection efficiency do not reflect an inherent characteristic of the perceptual system.

33.528 Developing a New Measure of the Useful Field of View for Use in Dynamic Real-World Scene Viewing

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In real-world contexts, such as driving, a person's breadth of attention, or useful field of view (UFOV), can have life or death consequences, with a narrower UFOV associated with increased accident risk (e.g., Clay et al., 2005). However, existing measures of the UFOV have important limitations. Some cannot be used in dynamic viewing of real-world scenes, while others (e.g., peripheral detection tasks) do not control for retinal eccentricity or eccentricity-dependent contrast sensitivity. The current experiment aimed to develop a novel measure of the UFOV that overcomes these limitations. Our dependent measure was the detection of extrafoveal image blur in real-world scenes as a secondary task, while participants concurrently engaged in an attention-demanding primary task. The retinal eccentricity of the image blur was controlled through gaze-contingent presentation on occasional single fixations. Eccentricity-dependent contrast sensitivity was held constant in the following way. Blurred images contained a circular region of high resolution (3°, 6°, or 9° radius) centered on fixation, with a constant level of low-pass filtered imagery beyond that eccentricity. Each eccentricity was paired with a unique blur level such that, in a single-task blur detection task, blur detectability was held constant across eccentricities. Our first experiment, which disallowed eye movements, used a within-subjects design (n = 16) and occasional briefly flashed photographs of real-world scenes, half of which were blurred, while monitoring the viewer's eyes to ensure central fixation. To measure the effects of cognitive load on blur detection, participants concurrently did an auditory N-back task (with N = 0, 2, or 3). Results showed that as N-back level increased, blur detection significantly decreased, but did not interact with eccentricity—consistent with a general interference effect rather than tunnel vision (Crundall, Underwood & Chapman, 1999). Follow-up experiments will allow free viewing of scenes, and occasionally present blur for single fixations.

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33.529 Visual Configuration affects spatial distribution of the attentional blink

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A recent study found that attentional blink impaired performance on the second target (T2) with the effect being weakest at the first target (T1) location and locations far away from T1 (Du, Abrams & Zhang, 2011). This finding of a U-shaped spatial distribution of AB is consistent with lateral inhibition theory and in sharp contrast to many previous studies (Jefferies & Di Lollo, 2009; Kawahara, 2002; Olivers, 2004). Present study manipulated the spatial configuration of multiple RSVP streams to examine whether the U-shaped spatial distribution of AB in Du et al. study (2011) was due to a circular configuration of visual stimuli. In Experiment 1, we replicated a U-shaped spatial distribution of AB as Du et al. study when presenting six RSVP streams on an imaginary circle with a diameter of 15 degree (Please see Figure 1 in supplementary material for results). However, Experiment 2 found a similar U-shaped distribution of AB even when diameter of the imaginary circle shrunk to 10 degree (Please see Figure 2 for details), indicating the U-shaped distribution of AB was not determined by spatial distance between T1 & T2 per se. In Experiment 3, we managed to present four RSVP streams at four random locations while maintaining the eccentricity of two targets as that in Experiment 1. And we found that T2 performance decreased as the distance between T1 and T2 increased (As Figure 3 showed, the AB was weakest at T1 location and strongest at locations 15 degree away from T1) . Therefore a U-shaped distribution of AB in Du et al. study (2011) was due to the circular configuration of visual stimuli rather than spatial separation between T1 and T2. In conclusion, the configuration of visual stimuli affects the spatial distribution of AB.

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33.530 Spatial Allocation of Attention: Motor Conflict Contributions

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Previous research has shown that presentation of a peripheral, irrelevant visual stimulus initially attracts attention to that location. However, following this initial reflexive capture of attention, attention is then biased away from that location—a phenomenon termed inhibition of return (IOR). Researchers debate the extent to which motor conflict contributes to the IOR effect. To further explore this question, we conducted an experiment employing different cue-target tasks and examined their effect on IOR. Participants were assigned to three conditions differing in response instructions. A Target-Only condition replicated the classic IOR procedure such that no responses were provided to the cues. A Same-Response condition required participants to make identical responses to the cue and target. A Different-Response condition required participants to provide different responses to the cue and target. In this experiment, we found that motor conflict contributed to IOR, but could not entirely account for it. In a second experiment, we increased the perceptual similarity of the cues and targets and found that in this situation the contribution of motor conflict to IOR increased.

Acknowledgement: NSERC

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33.531 Comparing the resolution of a working memory-based target template with the resolution of visual working memory itself

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The allocation of visual attention can be guided by a target template (Leonard & Egeth, 2008), and this template can be stored in visual working memory (VWM; Carlisle et al., 2011). Although resolution has become an important issue in the VWM literature (e.g., Zhang & Luck, 2008), little work has examined how the resolution of VWM is translated into the control of visually-guided saccadic behavior. To examine the resolution of attentional guidance, we recorded eye movements while participants performed a search task for a target with a small gap on either the top or bottom (other objects had gaps on the left or right). Each trial started with a precue indicating, with 100% validity, the precise color of the upcoming target. A search display then appeared consisting of 6 objects that were 180º away in color space (far-color objects), 3 target-color objects (one of which was the target) that exactly matched the precue, and 3 near-color objects. We varied the distance in color space between the near-color and the target-color (either 16º, 24º, 32º, or 40º) to measure the resolution of the search template. That is, we measured the probability that an object would be fixated as a function of its distance (in color space) from the precued target color. Manual reaction time increased as the near-color became more similar to the target-color, which was accompanied by an increase in the number of fixations on near-color objects. We also included a pure VWM task using similar displays, in which participants indicated which of two objects matched the previously presented color patch. Comparisons of the search task and the pure VWM task suggested that the template that guides search is substantially less precise than the underlying VWM representation.

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33.532 The breadth of attention modulates visible persistence

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Our recent work has revealed that the breadth (spatial extent) of attention influences the effective capacity of visual sensory (iconic) memory (Gmeindl, Jefferies, & Yantis, submitted). Here, we examine whether the breadth of attention might influence even the earliest substage of visual sensory memory, known as visible persistence. It has long been known that briefly presented stimuli remain momentarily visible even after they have physically disappeared. There is evidence that the transient orienting of attention reduces the temporal precision of visual processing (Yeshurun & Levy, 2003), which may reflect an attentional modulation of visible persistence (Visser & Enns, 2001), but there has been no systematic investigation of the relationship between the breadth of attention and visible persistence. In the current study, we manipulated the breadth of attention during a task that assesses the duration of visible persistence (Di Lollo, 1980). Twelve dots from a 5 x 5 matrix were presented in each of two successive displays separated by a blank inter-stimulus interval (ISI), which was varied systematically between 8 and 48 ms. Observers were to indicate which dot was missing from the 5 x 5 matrix. The two displays could be temporally integrated and the missing dot accurately identified if the duration of visible persistence exceeded the duration of the blank ISI. The deployment of a narrow focus of attention increased the duration of visible persistence relative to a broad focus of attention. Our findings dovetail with previous evidence that focal attention modulates the spatial resolution, contrast sensitivity, and temporal resolution of visual processing. These results suggest that one way in which the breadth of attention modulates the effective capacity of visual sensory memory is by influencing the duration of visible persistence.

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33.533 Alerting trumps space and time in social orienting

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Attentional selection is influenced by the reliability of the cue in signaling events in the environment (i.e., alertness), its utility in indicating the spatial location of events (i.e., spatial predictability), and its utility in indicating the timing of events in the environment (i.e., temporal predictability). We investigated the role of each of these components in social orienting. Participants were presented with a central eye gaze cue and were asked to detect peripheral targets. Alertness was manipulated by altering the cue's reliability in signaling the appearance of a target (low reliability; high reliability). Spatial utility was manipulated by altering the cue's predictiveness of the target's location (nonpredictive; predictive). Temporal utility was manipulated by altering the cue's predictiveness of when within a trial the target will appear (nonpredictive; predictive). This design allowed us to measure the isolated and combined contributions of alertness, spatial predictability, and temporal predictability on the magnitude of social orienting. We found that attentional effects were enhanced under conditions of high alertness, regardless of the cue's spatial or temporal utility. Cue's spatial predictiveness also led to the enhancement of the attentional effect, however the level of alertness modulated this result. Finally, the manipulation of the cue's temporal utility did not affect the magnitude of social orienting and furthermore did not interact with the cue's spatial utility or its alertness. Together, these data suggest additive effects of spatial and temporal orienting, and point to the critical role of alertness in social attention.

33.534 Selective attention in two hemispheres: How basic is the bilateral field advantage in object processing?

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Recent evidence from tasks like multiple object tracking (Alvarez & Cavanagh, 2005), crowding (Chakravarthi & Cavanagh, 2009) or number estimation (Delvenne et al., 2011) suggests superior visual processing of bilaterally compared to unilaterally presented information. This bilateral field advantage is interpreted as evidence for basic anatomical constraints on attentional selection of perceptual information. In order to critically evaluate the level of processing of this bilateral benefit we presented up to 6 items in an enumeration task using a forward masking paradigm (Di Lollo, 1980). On each trial, the targets were presented either in a single hemifield or in both hemifields. We had previously reported that the forward masking procedure fractionated the duration of visible persistence of the target items, allowing us to measure the time course of object individuation. Processing capacity was found to be a direct consequence of the time window of access to sensory information (Wutz, Caramazza & Melcher, ECVP 2011.). We hypothesized that if the bilateral field advantage reflects early visual constraints on object selection—based on independent resources within each hemisphere—then the rate of object individuation should be more rapid with bilateral presentation of the items. However, the rate of object individuation, as well as overall capacity, was identical with lateralized or bilateral presentations of the targets. Our results therefore support a later locus of the bilateral field advantage in attentional selection within high-level visual processes, perhaps limited to top-down deployment of attention.

33.535 Stimulus- and state-dependence of systematic bias in spatial attention: Additive effects of stimulus-size and time-on-task

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Systematic biases in spatial attention are a common finding. In the general population, a systematic leftward bias is typically observed (pseudoneglect), possibly as a consequence of right hemisphere dominance for visuospatial attention. However, this leftward bias can cross-over to a systematic rightward bias with changes in stimulus and state factors (such as line length and arousal). The processes governing these changes are still unknown. Here we tested models of spatial attention as to their ability to account for these effects. To this end, we experimentally manipulated both stimulus and state factors, while healthy participants performed a computerized version of a landmark task. State was manipulated by time-on-task (>1 hour) leading to increased fatigue and a reliable left- to rightward shift in spatial bias. Stimulus was manipulated by presenting long or short lines. An attenuation of the leftward bias was observed in short compared to long lines. Importantly, we found time-on-task and line length effects to be additive suggesting a common denominator for line bisection across all conditions, which is in disagreement with models that assume that bisection decisions in long and short lines are governed by distinct processes (Magnitude estimation vs. Global/local distinction). Our findings empha-

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size the dynamic rather than static nature of spatial biases in midline judgement. They are best captured by theories of spatial attention positing that spatial bias is flexibly modulated, and subject to interhemispheric balance which can change over time or conditions to accommodate task demands or reflect fatigue.

Acknowledgement: Economic and Social Research Council

33.536 **Directing selective attention influences the perception of apparent motion**

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The perception of apparent motion has been linked to attentive tracking (Cavanagh 1992; Verstraten, Cavanagh, & Labianca, 2000; Verstraten & Ashida, 2005). A strong version of this account predicts that the correspondence problem of what went where would be solved by the movement of spatial attention. We tested this prediction by determining whether driving attention in a specific direction causes an ambiguous stimulus to move in that direction. Participants viewed a 2-frame ambiguous apparent motion display that could be seen as two circles rotating clockwise or counterclockwise. In Experiment 1, we directed observers' selective attention to various locations by presenting a brief flash cue at one of eight possible locations. We found that the location of the cue systematically biased the perceived direction of rotation, suggesting that observers disambiguated apparent motion by selecting one of the circles in the display and tracking it over time. The results also showed that by default observers selected the top circle in the initial frame. In Experiment 2, we manipulated the location of the initial selection by inserting an identification task that required selective attention. The results showed that manipulating the initially selected object biased the perceived direction of rotation in a systematic way. These results suggest an important role of the distribution of selection in creating complex visual representations by maintaining object identity over time.

Multisensory processing: Mechanisms and models

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

33.537 **An alternative to explicit divisive normalization models**

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Probabilistic inference lies at the heart of many crucial brain processes, such as primary visual processing, attentional modulation, multi-sensory integration, reference frame transformations, decision making, etc. It is possible that inference is implemented by marginalization across variables through explicit divisive normalization. However, direct evidence for such processes in the brain is sparse and further, for all but the simplest distributions, explicit marginalization requires intractable normalization operations. Here, we argue that explicit divisive normalization is not the only way marginalization can be performed and we propose an alternative, physiologically more realistic mechanism. This alternative mechanism (implicit approximate normalization: IAN) is based on well-established parallel computing and machine learning principles and is functionally equivalent to divisive normalization without requiring intractable sums/integrals. Specifically, we implemented multi-layer feed-forward neural networks and trained them to carry out several tasks using a pseudo-Newton method with preconditioned conjugate gradient descent. Doing so, we explicitly modelled near optimal multi-sensory integration, reference frame transformations and both in combination. We did so using different neural coding schemes within the same network, i.e. probabilistic spatial codes and probabilistic joint codes. We also implemented comparable spiking networks with realistic synaptic dynamics, demonstrating the feasibility of IAN at the spiking neuron level. Our networks produce a wide range of behaviours, similar to observations of real neurons in the brain. These include inverse effectiveness, the spatial correspondence principle, super-additivity, gain-like modulations and multi-sensory suppression. One advantage of IAN is that it works regardless of the coding scheme used in individual neurons, while divisive normalization requires explicitly matching population codes. In addition, IAN does not need a neatly organized and regular connectivity structure between contributing neurons, such as required by divisive normalization. Overall, our study demonstrates that marginalizing operations can be carried out in simple networks of purely additive neurons without explicit divisive normalization.

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33.538 **V1 resting-state functional connectivity reflects polar angle and eccentricity both within and between hemispheres**

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Local functional connectivity is reported to represent retinotopic eccentricity (E) within visual cortex (Yeo et al, 2011 JNeurophysiol). We tested if V1 functional connectivity actually reflects cortical surface distance (D), or some combination of eccentricity and polar angle (PA), and if inter-hemispheric correlations are retinotopically organized. Eighteen subjects were scanned (150 or 160 TRs BOLD fMRI, TR=3, 3mm voxels, 3 Tesla) under constant darkness. Raw signals from each subject were combined within a V1 cortical-surface template (Hinds et al, 2009 Neuroimage). Following 2mm surface smoothing, cross-correlation matrices (3161x3161 cells) for within-hemisphere V1 vertices were generated for low temporal frequencies ($0.01<f<0.08$ Hz) for each subject. Each vertex was assigned a PA and E value based upon the location of the vertex within the V1 retinotopic surface template (Benson, Butt et al, submitted). The pattern of correlation values in the individual (and group averaged) resting matrices were then modeled with exponential decay functions of changes in E, PA, and D. The group data were fit with an R2 of 0.97, with significant loading upon ΔE, ΔPA, and ΔSD ($p<0.001$). Consistently, the ΔE component contributed more to the model than the ΔPA component ($p=0.02$), even accounting for the greater cortical extent of V1 along the E axis. The between-hemisphere correlation matrix was also obtained, in which each vertex was compared to a vertex in the opposite hemisphere. The correlation structure again reflected E and PA (p's <0.001), with a greater representation of E ($p<0.001$). As this resting retinotopic structure existed between hemispheres, the finding cannot be explained by (e.g.) physiologic artifact or digital smoothing. These results show that V1 functional connectivity reflects retinotopic organization, not just local smoothness.

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33.539 **Exocentric reference frames determine 2D orientation bias**

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Judgments of the orientations of 2D lines show systematic biases that can be described as exaggerating deviations from horizontal. These biases are not due to numeric estimation biases. An orientation of about 37° from horizontal is judged to be equidistant from horizontal and vertical. The same orientation is judged to be 45° from horizontal and 45° from vertical. One hypothesis concerning this distortion is an experience-based anisotropy in the distribution of orientation sensitive cells in visual cortex. An alternative view is that these biases are intrinsic to the encoding of spatial orientation. To tease apart these two possibilities we oriented observers at 45° from vertical and asked them to do two kinds of tasks. One task was a psychometric measurement of perceived vertical or horizontal using a forced choice method. Judgments of visual stimuli, presented in a circular aperture that removed any external visual references, were made either with respect to an egocentric (bodily) or exocentric (gravitational) reference frame. Over 150 participants were tested. Both within and between subjects, variability was much less for judgments made with respect to the exocentric (perceived gravitational) reference frame. Similarly, when required to make numeric estimates of orientation with respect to the two types of reference frame, estimates with respect to perceived gravitational frames exhibited the standard bias exaggerating deviations from horizontal. Estimates with respect to bodily frames did not. These findings are consistent with the precedence of gravitational reference frames in visual experience and imply that 2D orientation asymmetries between horizontal and vertical are not caused simply by biases in the distribution of early cortical orientation analyzers. Precision was greatest when observers were upright so that gravitational and bodily vertical were aligned, but for tilted observers, judgments made with respect to gravitational reference frames were most similar to judgments made upright.

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33.540 Postural and viewpoint oscillation effects on the perception of self-motion.

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Adding viewpoint oscillation to displays increases the likelihood of visually induced self-motion (vection), even though sensory conflict theories predict that it should generate significant and sustained visual-vestibular conflict. This effect has been shown in upright observers, for which the simulated self-motion and oscillation were congruent with or orthogonal to gravity. Here we examined whether this oscillation advantage for vection depends on the orientation of the body with respect to gravity. Observers in upright (seated and standing) and lying (supine, prone, and left side down) postures viewed displays of radial optic flow simulating forward/backward self-motion, with or without horizontal or vertical viewpoint oscillation. Vection magnitude (compared to a reference stimulus), onset, duration, and vection dropouts, were compared among postures. Viewpoint oscillation enhanced vection for all of the body postures tested. Vection also tended to be stronger in upright than in lying postures. Changing body orientation with respect to gravity was expected to alter the degree/saliency of the sensory conflict, and may explain the posture-based differences in vection magnitude. However, this does not explain why the oscillation advantage for vection persisted for all postures. Given that the upright posture and oscillating flow (the norm during real self-motion) improved vection, and lying postures and smooth flow (which are atypical in our experience of self-motion) impaired vection, we conclude that postural and oscillation based vection findings are better explained by ecology.

Acknowledgement: Canadian Space Agency

33.541 Unraveling the Hong Kong Peak Tram Illusion

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The Hong Kong Peak Tram Illusion is the perception of an exaggerated tilt to vertical buildings while ascending or descending Victoria Peak on the Peak Tram in Hong Kong. We have previously reported this effect to be multisensory in origin and based upon the confluence of input from positional, visual, and passive motion cues. We elaborate upon earlier investigations by introducing new apparatus to isolate contributions to the effect from three sensory modalities: vision, proprioception, and the vestibular system. Using a new tilt-matching task, four observers chose the tilt line which best matched their perceived tilt while the objective slope was simultaneously measured. The use of under-foot, under-buttocks, and behind-back wedges to compensate for body slant and return the torso to true vertical weakened the illusion, but only when used in combination, suggesting that proprioceptive and vestibular systems are co-dependent in their contribution to the effect. Perception of the illusion is further lessened by standing, which eliminates bodily cues and requires active balancing. Removal of some visual cues, such as the rod-and-frame effect, by use of a viewing box weakened the illusion independently of objective slope. Individual differences in observer data suggest variations in the way sensory information is integrated. Further investigation into causes of the effect will involve elimination of confounding visual factors, comparison of observations of particular stimuli, and may be facilitated by an offsite simulation of the illusion. The Hong Kong Peak Tram Illusion is a real-life phenomenon which strikingly reveals how the labyrinthine complexity of sensory integration may lead to a dramatic misperception of the world when conflicting cues interact.

33.542 Learning and memory consolidation effects of a drawing paradigm in the congenitally blind

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Introduction. Recently, we developed a memory-training paradigm based on non-visual drawing and demonstrated that the high-resolution primary visual cortex, V1, plays a role in implementing the concept of an amodal memory ‘sketchpad’ (Likova 2010, 2011). To reveal further brain regions whose role in memory retrieval emerges as a result of training, we ran a whole-brain pre/post-training analysis of the memory-related activation. Methods. The tasks were: Drawing guided solely by tactile memory (MD), tactile exploration and memorization (EM) of the complex images to be drawn, and control scribbling (S), each of 20 s duration, separated by 20 s rest-intervals. FMRI (Siemens 3T scanner) was run preceding one week of drawing training in the congenitally blind, and following a prolonged consolidation period. A fiber-optic motion-capture system recorded the drawing movements. Results and Conclusions. Before training, a functionally-unified network of hippocampal and temporal-lobe areas was strongly activated in the encoding EM task but non-responsive or even suppressed in the memory-retrieval MD task. Remarkably, this network was dramatically reorganized after training. The hippocampal region reversed its response pattern to become strongly MD-specific and non-responsive to the EM task. Moreover, a large EM-specific ventro-temporal strip segregated into a cascade of adjacent but functionally alternating regions. Coordinated with the hippocampus, a subset of this cascade transformed to become MD-specific, implying a memory-retrieval function emerging after the training. Contrasting patterns developed in the intervening regions. As expected, no response was observed in this network for the control (S) condition either pre- or post-training. The findings have multivalent implications, providing insights into the evolution of functional segregation as a result of learning and allowing us to evaluate novel hypotheses on cross-modal brain reorganization, as well as making potential contributions to advanced rehabilitation strategies.

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33.543 Blind Individuals Experience a Larger Body-Tilt Illusion than do the Sighted

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People generally exhibit a body-tilt illusion, experiencing an angle of 45° when tilted only 25°-35°. The illusion is larger when sensorially deprived, and decreases with added spatial information provided by either vision or audition. The illusion may have an ecological basis in that more tilt is experienced with body postures that detour recovery from falling (e.g. being compacted or leaning sideways). Independently, numerous studies with blind individuals document their increased non-visual sensitivity, such as superior ability in utilizing acoustic cues to judge spatial location. Such findings suggest that blind individuals likely differ from sighted in their propensity to process proprioceptive body tilt, particularly when acoustic information is available. The present study tests if blind individuals exhibit a weaker body-tilt illusion (consistent with more accurate non-visual sensory processing), or a stronger illusion (consistent with enhanced sensory resolution). We also examined if the tilt illusion systematically diminishes with increased salience of acoustic stimuli. We used an Aerotrim body-tilt machine to test 10 blind individuals and 8 sighted controls, each judging body-tilt at four levels of auditory salience, and with both eyes open versus closed. Our findings confirm that blind individuals experience a significantly larger body-tilt illusion, and that both blind and sighted populations exhibit systematic decreases in illusory tilt as auditory stimuli climb in salience through the progression of no sound, white noise, square wave, and baby crying stimuli. We also found an interaction with eyes open versus closed having no effect on blind participants, while the pattern with sighted participants replicates previous findings showing less of an illusion with eyes open. The pattern of findings is consistent with an ecological interpretation in which perceived body-tilt is systematically influenced by salience of acoustic stimuli and blind individuals, who presumably have enhanced non-visual senses, exhibit a stronger body-tilt illusion than do the sighted.

33.544 Functional imaging of shape processing in a blind echolocation expert

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We have previously reported that an early-blind echolocating individual showed robust occipital activation when he identified distant, silent objects based on the auditory information attained through echoes from his tongue clicks (Thaler, Arnott & Goodale, 2011, PLoS ONE, 6(5), e20162). In the present echolocation study, we investigated the extent to which the occipital activation reflected general auditory processing per se, as well as whether object feature processing recruited specific occipital regions. As in our previous study, binaural sound recordings were made as the participant stood in front of objects (i.e., a concave-facing bowl or a flat disc of the same diam-

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eter) and emitted echolocation clicks. Each object's surface was covered in either aluminium foil or a thin cotton-towel and each of the recordings was made in an anechoic chamber and again in a small reverberant alcove. All eight auditory stimuli (2 shapes x 2 surface compositions x 2 environments) were then randomly presented to the participant during a sparse-temporal scanning fMRI session in which the participant was asked to discern either the object's shape or surface, or to determine which environment the recording had occurred in. Relative to shape or surface composition judgments, whole-brain voxelwise analyses revealed that environment judgments strongly activated the right calcarine cortex, suggesting involvement of this area in general auditory processing. Interestingly, even though the participant was listening to the same stimulus set, discerning the object's shape preferentially activated the left occipital pole and angular gyrus to a greater extent than surface judgments. These shape-specific activations were slightly increased for the chamber compared to the more difficult alcove trials, arguing against a mere effect of task difficulty. Together, our results reaffirm this expert's use of the occipital lobe to accomplish echolocation, demonstrating the specific involvement of the left occipital pole in this particular shape processing task.

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33.545 **Parahippocampal cortex is involved in material processing through echolocation in blind echolocation experts**

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People, in addition to animals such as bats and dolphins, can utilize echolocation to navigate through their environments. In fact, there are blind people who have learned to navigate by emitting mouth clicks and listening to the returning echoes. Previous echolocation research has shown that blind people can use echoes from their own vocalizations to discriminate between different materials such as velvet or glass (Kellogg, W.N., 1962, Science 137: 399-404). Importantly, apart from providing a sound-reflecting surface, the materials were always silent. Here we present data from an fMRI experiment that investigated the neural activity underlying the processing of materials through echolocation. Three blind echolocation experts (all males) took part in the experiment. First, we made binaural sound recordings in the ears of each participant while he made clicks in the presence of one of three different materials (fleece, foliage or whiteboard), or while he made clicks in an empty room. During fMRI scanning these recordings were played back to participants. Remarkably, based on the recordings alone, participants were able to identify each of the three materials reliably, as well as the empty room. Furthermore, a whole brain analysis, in which we contrasted the brain activity that occurred when participants listened to material recordings versus when they listened to empty-room recordings, revealed a material-related increase in BOLD activation in a region of parahippocampal cortex. This region of parahippocampal cortex has previously been found to be involved in the processing of the material properties of objects signalled by visual or auditory cues (Arnott et al., 2008, NeuroImage 43: 368-378). Thus, our results are consistent with the idea that material processing by means of echolocation relies on a multi-modal material processing area in parahippocampal cortex.

Scene perception: Mechanisms and models

Sunday, May 13, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

33.547 **Neural Mechanisms of Camouflage-Breaking: A Human fMRI Study**

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Camouflage represents an extreme case of figure-ground segregation whereby a target object, even when in 'plain view', is difficult to distinguish from its background. Neural mechanisms by which we recognize a camouflaged object, i.e., break its camouflage, are largely unclear. To characterize the neural responses underlying camouflage-breaking, we carried out two human fMRI experiments. The first experiment used a rapid, event-related design in which subjects had to detect a novel 'digital embryo' target camouflaged against a background of a large number of distractor digital embryos (Hegdé et al, JOV 6:677, 2006). We found that the responses in many regions of interest (ROIs), most notably fusiform gyrus (FG) and superior temporal sulcus (STS) were significantly larger during those trials in which the subjects (N = 13) correctly reported the presence or absence of a target, compared to the responses during incorrect trials ($p < 0.05$, corrected for multiple comparisons). To assess the extent to which the response patterns are independent of the experimental conditions, we carried out a second experiment using a time-resolved design and stimuli in which the target was a human face camouflaged against uniform background texture. The response patterns of many brain regions, including FG and STS, were similar to those in the first experiment, indicating that the responses were not idiosyncratic to the nature of the target or of the background. On the other hand, the BOLD responses in the intraparietal sulcus (IPS) were suppressed below baseline levels during behaviorally correct trials in the second experiment, while the corresponding responses were enhanced above baseline levels in the second experiment. Together, these results suggest, although do not prove, that camouflage-breaking may involve a 'core' set of brain regions whose responses are largely invariant to the nature of the target and of the background.

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33.548 **TOS is causally involved in scene processing**

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Functional magnetic resonance imaging (fMRI) has revealed a cortical network for complex visual scene processing, consisting of three regions – the parahippocampal place area (PPA), retrosplenial complex (RSC), and transverse occipital sulcus (TOS). Although past research has demonstrated that these regions respond more strongly to scenes than objects, it cannot be inferred from such findings that these regions are causally involved in scene processing. To test the causal role of TOS, we delivered transcranial magnetic stimulation (TMS) to right TOS and the nearby face-selective right occipital face area (OFA) while participants performed discrimination tasks involving scenes and faces. (PPA and RSC are too medial to be accessible to TMS.) We found a double dissociation: TMS over TOS impaired discrimination of scenes but not faces, while TMS over OFA impaired discrimination of faces but not scenes. This finding provides the first evidence that TOS is causally involved in scene processing, and further shows that this causal role is selective for scene perception.

Acknowledgement: NIH grant EY13455 to NK

33.549 **The contribution of object layout and object identity to scene representations in the brain**

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When we look at scenes, we notice not only what objects are in a scene but also how these objects are arranged in a scene. How do object identity and layout contribute to scene representation in the brain? Previous imaging studies have identified one object-selective cortical region in lateral occipital complex (LOC) and several scene-selective cortical regions, including the parahippocampal place area (PPA), the retrosplenial cortex (RSC) and the transverse occipital sulcus (TOS). Using an fMRI adaptation paradigm, we examined how activities in these four regions (LOC, PPA, RSC, and TOS) are modulated by object identity and object layout changes in scenes. In each trial, participants were shown a sequential presentation of two scene images. Compared to the first image, the second image was 72% in size and could be either identical to the first image, containing only object layout change, containing only object identity change (in which all the objects in a scene changed identity), or containing both object layout and identity changes. Participants judged whether there were any difference between the two scenes. Behavioral results show that people were more accurate and faster with object layout than with object identity changes. Using a regions-of-interest approach, preliminary fMRI results showed that PPA

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and LOC were sensitive to both object identity and object layout changes, with the effects from the two types of changes being additive; TOS and RSC, on the other hand, only showed sensitivity to object layout changes. These results suggest that the contribution of object identity and object layout to scene representation differ in different brain areas.

33.550 The Impact of Density and Ratio on Object-Ensemble Representation in Anterior-Medial Ventral Visual Cortex

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Behavioral research has demonstrated that observers can extract summary statistics from large collections, or ensembles, of objects. We recently demonstrated that anterior-medial ventral visual cortex, along the collateral sulcus and parahippocampal gyrus and overlapping with the scene-sensitive parahippocampal place area, exhibited fMRI-adaptation whenever object-ensemble statistics repeated (i.e., adaptation across different photographs depicting the same ensemble). To understand the nature of this neural ensemble representation, here we investigated the encoding of object density in an ensemble. Observers viewed sequences of different photographs depicting the same ensemble with either fixed or varying density (achieved by changing the spacing between objects). For comparison, we presented sequences of identical photographs and sequences of photographs depicting different ensembles. In anterior-medial ventral visual cortex, compared to the different ensemble condition, we observed fMRI-adaptation whenever ensemble features repeated, even when density varied. This suggests that object density is not part of the neural ensemble representation in this brain region, possibly because such density manipulations may be seen as accidental, rather than reflecting an intrinsic property of ensembles. But perhaps the relative density of different types of objects in an ensemble holds greater ecological significance in everyday visual perception. To test this idea, we conducted a second experiment, and instead of varying density by varying spacing, we varied relative density by varying the ratio of two types of objects comprising an ensemble. Interestingly, we observed a release from adaptation with this ratio change. Taken together, these results indicate that while anterior-medial ventral visual cortex is insensitive to density changes resulting from changes in spacing, it does code the proportion, or relative density, of different objects comprising an ensemble. Thus object-ensemble processing in anterior-medial ventral visual cortex seems to depend on high-level information, such as the ratio of ensemble elements, rather than low-level information, such as spacing/spatial frequency.

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33.551 TMS over extrastriate body area (EBA) impairs person detection in briefly-presented real-world scenes

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People are very good at detecting familiar object categories in briefly presented pictures of complex natural scenes. In 2 experiments, we used fMRI-guided transcranial magnetic stimulation (TMS) to investigate the role of the extrastriate body area (EBA) in the detection of people in complex natural scenes. In experiment 1, subjects indicated - in different blocks - whether people or cars were present in a briefly (50 ms) presented picture. We found that the accuracy of detecting people in natural scenes was decreased after TMS over the right EBA (5 pulses at -200, -100, 0, 100, 200 ms) compared to sham stimulation. Performance on the car detection task was unaffected by TMS. In experiment 2, we investigated at what stage the EBA was crucially involved in the detection of people. We applied TMS either before (-200, -100 ms) or after stimulus onset (100, 200 ms), and found that only TMS post stimulus onset decreased detection performance. These findings demonstrate that a TMS-induced virtual lesion in the EBA results in impaired detection of people in complex natural scenes. They extend previous findings that delayed-match-to-sample discrimination tasks with isolated body stimuli are impaired by TMS over the EBA, and by occipitotemporal brain lesions incorporating the surrounding cortex. We conclude that the EBA plays a causal role in the initial extraction of body-related features from complex visual input.

33.552 Transcranial Magnetic Stimulation to the Transverse Occipital Sulcus Affects Scene but not Object Processing

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Traditionally, it was theorized that the human visual system identifies and classifies scenes in a bottom-up, object-centered approach, such that scene processing can only occur once the objects within a scene are identified. Conversely, recent research suggests a more top-down approach, such that the global image features of a scene are sufficient for the recognition and categorization of a scene. Moreover, we have shown that disrupting object processing with repetitive transcranial magnetic stimulation (rTMS) actually enhances scene processing possibly through a release of inhibitory mechanisms (Mullin & Steeves, 2011). The present study examines the effects of rTMS to the left transverse occipital sulcus (TOS), an area implicated in scene perception. In two separate sessions, we performed online functionally-guided rTMS to the left TOS and the vertex (control site) while participants performed an object and scene classification task. Each session included no rTMS trials. Participants were presented with a stream of scene and object images and were asked to indicate as quickly and accurately as possible whether they were manmade or natural. Preliminary results suggest that unlike rTMS to object areas, which produces a release of inhibition on scene processing, inhibiting the TOS does not affect object categorization. This suggests that there is not a mutual release of inhibition from scenes to objects in this top-down approach to image processing. However, transiently interrupting the TOS resulted in longer latencies and lower accuracy rates for scene processing compared to the control conditions. Given that the parahippocampal place area (PPA), a key region in the scene processing network, presumably remains intact with rTMS to the TOS, this suggests that the TOS must nonetheless play an important role in this network.

33.553 Neural basis of affective visual processing for fearful scenes

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Visual processing of scenes provides important cues for affective perception. While many previous studies investigated affective perception of facial expressions, the neural basis of affective visual processing for scenes remains largely unknown. By using fMRI, we measured brain activation when participants were shown gray-scale scene pictures with a wide range of contents and of various levels of rated fearfulness. In each scan run, 30 images with 5 levels of rated fearfulness were shown in a random sequence to participants for 2s each and followed by a 12s fixation period. Participants were asked to do a 2AFC task judging whether the image presented was fearful or not. Each participant went through 9 of such scan runs. In addition, regions of interest (ROI) in temporal and occipital lobes were functionally localized with separate scan runs by contrasting brain activation corresponding to an independent set of fearful images versus scrambled images. Our results suggest that brain activity in ROIs of the fusiform gyrus and lateral occipital cortex (LOC) closely correlated with the level of fearfulness of the scenes. By contrast, other visual areas in the occipital lobe were found to be insensitive to the varying degrees of fearfulness in our stimuli, suggesting that our results in the fusiform and LOC were unlikely caused by general arousal of attention status. Brain activity in other ROIs is analyzed for comparisons. Moreover, multivariate pattern analysis is performed to further evaluate the functional role of these ROIs. Our results provide brain imaging evidence for the neural basis of affective visual processing for fearful scenes.

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33.554 Recent experience shapes current perception: Perceptual autocorrelation of visual samples is indexed by the P300

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Purpose: Perception is not isolated, but depends largely on recent experience. We used ERPs to isolate a cortical marker of the information gained from multiple samples of a visual stimulus over time. Specifically, we measured the extent to which the intervening delay between successive visual numerosity estimates modulated the amplitude of the P300, an index of contextual updating in working memory. Methods: We recorded EEG activity while observers estimated the number of dots in briefly presented displays. Although the positions of individual dots were randomized, numerosity was repeated one, two, three, four, or a random number of trials later (n-back). To assess the degree of dependence within response pairs, we computed the precision gained by averaging two estimates of the same numerosity and conjointly measured the amplitude of the P300 time-locked to the onset of the displays. Results: Although participants were not aware that numerosities regularly repeated, the average of two judgments of a given numerosity became more independent, and therefore more informative, as they were made further apart in time. In accordance with this behavioral effect, the amplitude of the posterior parietal P300 increased as an inverse function of n-back. Conclusions: We uncovered an inverse modulation of the P300 as a function of increasing intervening delay between two perceptual estimates. As the P300 reflects the extent to which a stimulus is consolidated into working memory, our results support the idea that an implicit memory trace of a visual pattern influences perception of subsequent retinal images, and offers a novel means of tracking the extent to which perceptions are built from multiple samples over time. This perceptual autocorrelation suggests a mechanism to mediate between the contrasting needs for (1) sufficient acuity to detect changes and represent salient stimuli, and (2) enough abstraction to maintain perceptual continuity in a noisy environment.

33.555 **Intuitive mechanics in visual reasoning about complex scenes with unknown forces**

Peter Battaglia[1](pbatt@mit.edu), Jessica Hamrick[1,2], Joshua Tenenbaum[1,2]; [1]BCS, MIT, [2]Computer Science, MIT

People have a powerful “physical intelligence” -- the capacity to infer physical properties of objects and predict future states in complex dynamical scenes -- which is central to how they interpret their environment and plan safe and effective actions. With little or no training and only a short visual presentation, people can easily judge subtle properties of scenes and anticipate future events, even when uncertain factors, like external forces, and more complex properties, like friction and physical connectedness, are involved. For instance, when you place a cup on your desk, you visually inspect the scene and identify locations likely to be robust to someone bumping it, factoring in surface friction and connections between objects. We hypothesize that the brain relies on a sophisticated system of knowledge about physics, i.e. an “intuitive mechanics”, which applies to a wide variety of common arrangements of objects, and which allows it to make these rich inferences and plans. We developed a probabilistic model to capture this hypothesis, which input visual stimuli containing arrangements of objects, and which predicted potential physical consequences under external forces, friction, and connectedness. To evaluate the model in scenarios like the desk example above, we presented participants with scenes depicting virtual tables with random stacks of red and yellow blocks, and asked them to judge which color would more likely fall off if an unknown bump were applied. In some cases we informed them, either verbally or visually, that some colors were connected (i.e. reds are attached to reds), or that some colors were subject to greater or lesser friction, and measured whether and how people’s judgments responded to these manipulations. We compared people with our model and found good correspondence; in particular, people demonstrated accurate reasoning about potential external bumps and appropriate sensitivity to friction and connectedness properties.

33.556 **Physics knowledge aids object perception in dynamic scenes**

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People naturally infer unobservable physical properties such as mass, elasticity, and friction in many uncertain and complex scenarios. For example, when picking up a cup of coffee it is useful to determine the weight; similarly, when walking around in socks, it is useful to infer how slippery the floor is. We hypothesize that humans reason about such situations using an ``intuitive mechanics’’ that allows physical knowledge to inform visual ``beliefs’’ about a dynamic scene as it unfolds over time. To test people’s ability to make these inferences, we showed participants simulated 2D movies of arrangements of red and yellow building blocks colliding, collapsing, or remaining upright. They then estimated properties such as the mass ratio or elasticity between differently colored blocks. In different trials we presented static ``previews’’ of the scene for varying durations in order to modulate participants’ initial visual precision at estimating the blocks’ positions. People’s judgments were sensitive to variations in mass ratio, elasticity, and preview length, making more consistent and accurate judgments when allowed a longer preview. We compared these results with a probabilistic time-series observer model which makes its judgments using knowledge of collision dynamics and Newtonian mechanics in a simulation-based inference procedure. Visual precision in the model is represented through uncertainty in block positions; both human judgments and model predictions vary proportionally with the level of uncertainty, implying an important role for visual precision in physical reasoning. Our model is additionally designed to handle arbitrarily complex situations and can predict people’s judgments in scenarios ranging from simple two-body collisions to complex stacks of objects. We conclude that human judgments of latent physical properties depend both on the precision of visual scene interpretation and knowledge of how physical laws influence the scene’s dynamics.

33.557 **Interrupting foveal feedback representation impairs visual discrimination in the periphery**

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A previous study showed a novel form of feedback in the visual system – foveal retinotopic cortex conveys information about stimuli presented in the periphery (Williams et al., 2008). However, the behavioral relevance of this feedback representation remains unclear – does it provide a benefit to processing of the peripheral stimuli? To address this question, we measured subjects’ visual discrimination performance in the periphery while interrupting foveal representation. During each trial, subjects reported the orientation of a grating (left-tilted or right-tilted) briefly presented in a peripheral location while fixating at the center. At the same time, another grating with the same orientation as, or different orientation from, the peripheral target grating was briefly presented at the fovea and masked (to render it invisible). When the foveal grating’s orientation differed from that of the peripheral grating, subjects showed impaired visual discrimination in the periphery, compared with when the two gratings’ orientation matched each other. This occurred even though subjects did not consciously perceive the foveal grating. These results indicate that interrupting foveal feedback information can impair our ability to discriminate peripheral visual stimuli, suggesting functional significance of foveal feedback representation.

33.558 **Categorization of line drawings of natural scenes using non-accidental properties matches human behavior**

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Humans can perceive the category of natural scenes accurately at a brief glance (Potter 1975), even when the scenes are presented as line drawings (Walther et al. 2011). What are the features underlying this ability? Biederman postulated that we use non-accidental properties, such as collinearity, curvature, or specific types of vertices, for the recognition of objects and their spatial relations (Biederman 1987). Practical tests of this model with real-world images have so far failed due to the challenge of extracting these non-accidental properties from photographic images. For our work we used line drawings that were generated by artists, who digitally traced the outlines in photographs of natural scenes. Having the exact coordinates of the artists’ pen strokes available allowed us to define non-accidental properties and other scene statistics using linear algebra. Specifically, we automatically extracted the distributions of contour length, curvature, orientation, angle between lines in intersections, as well as the counts of T, X, and Y junctions as defined by Biederman. We used these features to train a classifier to discriminate between six categories of natural scenes (beaches, city streets, forests, highways, mountains, and offices). The classifier could correctly identify the category for 86% of the line drawings in a left-out test set (chance: 16.7%). To assess the relevance of these features for human behavior, we compared the errors made by the classifier for the different types of features with the errors made by human participants in a six-alternative forced-choice categorization task of briefly presented and masked line drawings. Correlations of the off-diagonal elements of the confusion matrices were significant at $p<0.05$ for intersection angles ($r=0.44$), junction type ($r=0.41$) and contour curvature ($r=0.37$). This match between non-accidental properties and human behavior serves as experimental confirmation of the importance of these features for the perception of natural scenes.

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33.559 Spatiotemporal dynamics and neural synchrony during perception of threatening vs. merely negative visual scenes

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Current theories of affective perception hold that all negative stimuli are threatening and aversive. This conflicts with our everyday experience in which some negative sights, such as accident scenes, attract, while others repel. A earlier behavioral study (Kveraga et al., 2011) showed that humans indeed discriminate reliably between stimuli that are merely negative, and those that are negative and threatening, identifying threats more quickly. The goal of the present set of experiments was to understand the spatiotemporal evolution of perceptual processes underlying this discrimination ability in the human brain. Color photographs of scenes from a set validated in behavioral studies were presented in fMRI and combined MEG/EEG studies. The scenes were grouped into four affective conditions: direct-threat negative, indirect-threat negative, non-threat negative, and non-threat non-negative. A 1-back memory task was employed to ensure participant attention to the scenes. Threat scenes evoked greater fMRI activations in the amygdala and periaqueductal gray, as well as earlier and stronger MEG/EEG activations in anterior temporal and orbitofrontal cortices than negative non-threat scenes. Phase synchrony between anterior temporal and orbitofrontal cortices increased in the β and γ bands for threat vs. negative scenes. Conversely, negative scenes evoked greater fMRI activity in parahippocampal and medial parietal cortices and decreased MEG/EEG phase synchrony, particularly in the α band, than threat scenes. Lastly, ventrolateral prefrontal cortex, implicated in threat reappraisal (Wager et al., 2008) was activated earlier and showed earlier synchrony with orbitofrontal cortex for negative than for threat scenes. We conclude that the potential to inflict harm is assessed early and automatically in visual stimuli. Negative stimuli can repel or attract closer scrutiny, depending on their current threat potential, and dynamically shifting balance of activity between medial temporal and prefrontal cortical regions likely underlies behavioral differences in evaluating threats and merely negative visual stimuli.

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33.560 Automatic neural coding of open and closed scenes in RSC and PPA during visual search

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Scene processing produces neural representations in a number of cortical regions that support various tasks, including visual search. Recent evidence suggests that during scene processing the responses of the parahippocampal place area (PPA) are modulated by spatial boundaries but not categorical or content aspects (Kravitz et al., 2011; Park et al., 2011). Unknown is whether the neural coding of spatial layout persists when observers are engaged in a visual search task requiring a decision that is orthogonal to judging the spatial layout of scenes or having to recognize the scenes. Using event-related fMRI and a single-trial multivariate pattern analysis (MVPA), we show that several visual areas can reliably discriminate scene spatial layout (open vs. closed space) when observers are doing a visual search task. Observers viewed 640 briefly presented (250 ms) diverse real-world scenes and searched for a target object that was specified by a cue word that preceded each scene. Each scene was presented only once and targets were present in 50% of the scenes. Observers reported their present/absent decision using an 8-point confidence rating. Importantly, the observer's discrimination (present/absent) was orthogonal to the discrimination of the MVPA (open/closed scene). Single-trial MVPA was used to discriminate between the spatial layout categories of scenes (open/closed scene) in regions identified by standard localizers. Classifier performance indicated that RSC, PPA and V3B were significantly greater than chance for open/closed space discrimination, but RSC and PPA had the best performance. Low-level visual areas (V1-V4, MT), object-, and face- selective areas did not predict spatial layout above chance. The finding that RSC and PPA can discriminate between the open and closed images when observers are engaged in an orthogonal task supports the conclusion that areas within the scene processing network are involved in automatically coding the spatial layout of natural scenes.

Acknowledgement: Army grant W911NF-09-D-0001

Sunday Afternoon Talks

Spatial vision: Crowding

Sunday, May 13, 2:30 - 4:15 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: John Greenwood

34.11, *2:30 pm*

A remote target repetition reduces crowding

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In peripheral vision, it is harder to identify a target letter when it is flanked by other nearby letters. This crowding effect occurs when the flankers fall within a well-defined interference zone extending around the target to about 1/3 to 1/2 of the target's eccentricity (the critical spacing). Here we extended a study of Geiger and Lettvin (1986) and found that crowding can be reduced by a single item presented far outside the critical spacing, either at the fovea or in the opposite visual field, when the remote item matches the crowded target. Observers were presented with an array of three horizontally arranged items, letters and numbers, with the target at the center. Stimuli were presented randomly to the left or right of fixation. Additionally, a single number or letter was presented either at fixation or at the mirror location opposite to the crowding stimulus. Observers indicated whether the target was a number or a letter. To ensure the allocation of attention to both positions, observers also indicated whether the remote item was the same as the crowded target, though the single item was not a reliable cue to the crowded target identity. Nonetheless, performance in the crowding task was improved when the single item was the same as the target compared to when they were different, indicating that target repetitions far from the target can reduce crowding. We suggest that this result is due to long-range grouping processes that precede crowding.

Acknowledgement: Agence Nationale de la Recherche, Marie Curie Intra-European Fellowship

34.12, *2:45 pm*

Reading faster by reducing crowding

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There is great interest in designing fonts and electronic methods of display to increase reading speed, but so far, the improvements have been modest, a few percent. Visual span is the number of letters that can be identified with a single fixation. It is approximately 10 letters, centered on fixation. Letters beyond this are too crowded to recognize. As a result, saccades must be executed to the next set of letters. If crowding can be reduced so that more letters can be identified with each glimpse, reading speed should increase proportionally. Crowding is weak when target and flankers are dissimilar. Consequently, text that alternates in color from letter to letter (black-white-black) should increase reading speed. Yet this does not work (Chung & Mansfield, 2009). In a previous experiment we found that the alternation leads to grouping of letters, which increases crowding instead of reducing it. In an attempt to reduce crowding we ensure that letter-letter dissimilarities do not form a pattern. Observers read a page of text as quickly as they can while maintaining comprehension. White text is presented on a gray screen. Using a gaze-contingent, a length of text (slightly larger than estimated visual span) centered on current fixation is rendered black. The outermost black letters should now be uncrowded by the surrounding white letters. This should increase the span size and result in increased reading speed. Indeed, we find that subjects read about 18% faster using our gaze-contingent paradigm [$t(3)=13.8837$, $p<0.001$] than with unaltered text. We manipulate various stimulus factors (within the gaze-contingent window) such as color, size, and contrast, all with similar effects. We conclude that with a gaze contingent display, reading speed can be increased.

34.13, *3:00 pm*

Crowding modulates activity in V1

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Crowding refers to the impairment of object identification in peripheral vision due to clutter. Theories on crowding have implicated the involvement of a range of cortical regions. While it is quite probable that crowding occurs at multiple stages of visual processing, identifying the earliest site of crowding can provide the strongest constraint on the basic mechanism of crowding. Previous attempts with fMRI were limited by the need to use indirect and less sensitive methods such as adaptation or functional connectivity to avoid confounds, and large peripheral targets to obtain good isolation of target-evoked activity, but at the cost of a weak crowding effect. In contrast, the present study measures the average signal evoked jointly by the target and flankers within a region of interest (ROI). Using stimuli that yield a robust crowding effect, we made simple and direct measurements of BOLD signal amplitude. We found that when a subject's attention was directed away from the stimulus, adding a center letter between two flankers in a non-crowded configuration naturally led to a signal increase in the inclusive ROI. However, in a crowded configuration, adding a center letter either led to no increase in V1 for tangentially arranged flankers (a configuration that induces weaker crowding) or a net decrease for radially arranged flankers (stronger crowding). This net decrease found in the ROI that included the flanking and center letters rules out local response saturation as an explanation. Surround suppression also cannot be responsible since there was no significant difference in contrast threshold for detecting the center letter in tangential and radial flanker arrangements. These results are consistent with our earlier finding that crowding reduced BOLD amplitude in V1 while subjects identified the center letter. Crowding clearly modulates activity in V1, implying a basic mechanism that involves elementary features and low-level visual processing.

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34.14, *3:15 pm*

Shared spatial uncertainty for crowding and saccades

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Crowding - the disruptive influence of clutter on object recognition - occurs when flanker objects fall within an "interference zone" around a target and features from each object combine. These zones scale with eccentricity and show a characteristic teardrop shape, oriented radially from fixation. Precisely why crowding follows this pattern is unclear. Interestingly, saccadic eye movements show a similar teardrop-shaped landing distribution around an intended target location. To determine whether crowding and saccadic landing errors share a common positional uncertainty, we combined the two tasks by having observers make eye movements to crowded targets. The target was a circular clock, with a central point and radius-length stroke oriented in a cardinal direction, flanked by two similar elements. After target offset, observers (n=5) made a saccade to the target centre and then indicated its stroke orientation (4AFC). We measured four (cardinal) saccade directions, at 4 and 8 degrees eccentricity, with flankers along either radial or tangential axes to fixation. From identification performance (as a function of element spacing) we derived "crowding interference zones" and from saccade landing positions we derived "saccadic-error zones". Crowding and saccadic-error zones show a similar elliptical anisotropy, with 2-3 times more error in the radial than tangential direction. Both also scale with eccentricity, doubling between 4-8 degrees. This gives a significant correlation between the two zone-types, with saccade zones around one-half to one-third the scale of crowding. When flankers are inside the crowding zone, saccades would therefore fall on both target and flanker locations. Saccades would only isolate the target accurately once flanker separations exceed the crowding zone. Our results demonstrate the

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potential linkage between the coding of saccade locations and crowding. We propose that "pointers" within the saccadic map are involved in determining the spatial range of feature pooling in peripheral vision.

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34.15, *3:30 pm*

Orientation tuning in color vision measured in the absence of contrast gain control

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It is thought that measuring response tuning using sinewave masking confounds the effects of the within channel response with the more broadly tuned cross-channel gain controls activated by the use of high contrast mask stimuli (Cass et al., JOV 9(12), 2009; Meese & Holmes, JOV 10(12), 2010). Here we use a method of subthreshold summation to measure the orientation tuning of color vision at very low contrasts, without the influence of contrast gain controls. Methods: Stimuli were oriented sine-wave gratings (sf = 1.5 cpd) in a circular patch (10 degs) with rasied cosine edges. Gratings were presented alone or as overlaid pairs to form a plaid. The orientation difference between the two gratings was varied from 0 to 90 degs. For each plaid angle, psychometric functions were obtained for the detection of each grating and the "plaid", and a summation ratio was determined. Orientation tuning was measured for isoluminant red-green and achromatic stimuli presented monocularly. Results: Summation ratios as a function of orientation difference were fitted with Gaussian functions with an offset parameter (~1.3 dB) to take into account probability summation. At this spatial frequency, we find orientation-tuned responses for color vision that are similar to those obtained for achromatic vision with a bandwidth (HWHH) of 12.0 ± 3.8 degs for color and 9.0 ± 2.4 degs for achromatic stimuli (average of three subjects). Conclusion: Subthreshold summation reveals orientation tuning in color vision at mid spatial frequencies, whereas masking reveals very broad or isotropic effects (Medina & Mullen, JOV 9(3), 2009). This difference is likely due to the influence of contrast gain control in the masking paradigm. Orientation tuning for color contrast that matches that for achromatic contrast supports a primary role for color vision in shape perception.

Acknowledgement: CIHR grant MOP-10819 to KTM

34.16, *3:45 pm*

Theory and data for area summation of contrast with and without uncertainty: Evidence for a noisy integrator model

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Contrast sensitivity improves with the area of a sine-wave grating, but why? The standard account attributes this to spatial probability summation (e.g. A MAX operator) between independent noisy detectors. However, this does not fit well with hierarchical models of neuronal convergence, which suggest a more direct form of spatial integration. Deciding between these alternatives has been difficult because in each case, good model fits to summation functions are achieved with a single free parameter: the level of uncertainty for MAX pooling or the severity of the nonlinear transducer for linear pooling. The slope of the psychometric function also depends on each of these parameters. We cannot control intrinsic uncertainty but did control extrinsic uncertainty by either blocking or interleaving centrally placed target gratings with various diameters (1:32 cycles) using 2IFC and MCS. Area summation curves were steep over the first 8 grating cycles, becoming shallower thereafter. For the smaller stimuli, sensitivity was significantly worse for the interleaved design than for the blocked design suggesting that our manipulation of uncertainty was successful. However, neither stimulus area nor blocking affected the slope of the psychometric function. We derived stochastic model predictions for an inhomogeneous retinal field, noisy mechanisms and extrinsic uncertainty that depended on experimental design. The contrast transducer was either linear (C1.0) or nonlinear (C2.0), and pooling was either linear or a MAX operation. There was either no intrinsic uncertainty, or it was fixed, or it was proportional to stimulus size. Of these 10 canonical models, only the nonlinear transducer with linear pooling (the energy model) described the summation functions and the slopes of the psychometric functions for both experimental designs. We conclude that in previous studies, the effects of a square-law transducer followed by linear summation of noise with the signal have combined to masquerade as probability summation.

Acknowledgement: EPSRC UK (EP/H000038/1)

34.17, *4:00 pm*

Adaptation aftereffects in the perception of radiological images

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Radiologists must classify and interpret medical images on the basis of visual inspection. We are examining how an observer's visual sensitivity and perception might change as they view and thus adapt to the characteristic properties of radiological scans. Measurements were focused on the effects of adaptation to images of normal mammograms, and were tested in observers who were not radiologists. These scans have steeper power spectra (slopes of ~-3) than natural images (~-2) and thus are physically blurry. To test for adaptation specific to this blur, we measured contrast sensitivity for Gabor patches after observers viewed a sequence of randomly sampled sections from mammograms. Sensitivity was selectively reduced at lower spatial frequencies (less than ~2 c/deg), consistent with an adaptation to the low-frequency bias in the images. However, similar sensitivity losses were also found when the images were sharpened to have more "natural" spectra, suggesting that the blur in the scans was not sufficient to substantially change threshold sensitivity relative to the observer's natural operating state. In contrast, aftereffects specific to the image blur were found when observers instead judged the perceived blur within the images, by adjusting the spectral slope of a comparison image presented to an unadapted retinal location. Strong aftereffects in the appearance of the images were also found when observers judged the perceived texture of the images. For example, tissue density in mammograms is routinely classified and ranges from "dense" to "fatty." Adaptation to dense images caused an intermediate image to appear more fatty and vice versa. Our results suggest that observers can selectively adapt to the properties of radiological images, and that this selectivity could especially impact the perceived textural characteristics of the images.

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Perception and action: Interception and control

Sunday, May 13, 2:30 - 4:15 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Joan Lopez-Moliner

34.21, *2:30 pm*

Interception of parabolic balls: uncertainty of arrival time modulates hand closure movements

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Previous studies have shown that advance information (more certainty) about target static location increases movement time in reaching tasks. On the other hand, fast movement times are observed when we know when to intercept a moving object and have little time. It is unclear, however, how uncertainty will affect movement time when we have to rely on uncertain predictions based on early parts of a trajectory. I address this question in one Experiment in which subjects wearing a data glove had to catch balls in a VR setting. Four horizontal velocities (HV) and four initial vertical velocities (VV) resulted in 16 different trajectories with four flying times (0.61, 0.78, 0.94 and 1.11 seconds). The same trajectories were shown in 3 viewing conditions (early, late and full path). In half of the sessions feedback on the action success was given. Results show that accuracy was similar across viewing conditions but the contribution of movement initiation and movement time to reducing temporal error was different. Subjects started to close the hand earlier and performed slower closing movements when they saw the initial part of the trajectory only. This was especially so for longer flying times which implied larger VVs and, therefore, prediction relied more on elevation angle than image expansion. On the contrary, action was initiated later and hand closing was faster in the late and full vision conditions. Furthermore, action started according to a rate of expansion threshold only when the last part of the path was available and VVs were small (smaller flying times). Absence of feedback led to longer movement times especially in conditions that subjects had to rely on predictive information. I suggest that longer movement times increase temporal accuracy under the uncertainty of predictive information and this strategy is further promoted when feedback is missing.

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34.22, *2:45 pm*

The motor error distribution implicit in planning of movement in a speeded reaching task compared to the true error distribution

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Zhang, Daw & Maloney (2011, VSS) developed a 2-IFC task that allowed us to compare the motor error distribution implicit in a subject's choices between targets differing in shape to his actual motor error distribution. Subjects' implicit distributions typically differed from their actual (anisotropic Gaussian) error distributions. Here we use this task to estimate subjects' implicit distributions with targets that were composed of multiple, disjoint regions. The weight that subjects gave to regions of the target near to and far from their aim point allowed us to estimate the tails and variances of their implicit distributions. Methods: Targets were three equally-spaced vertical stripes (SSS) or a single vertical stripe (S). The widths of each stripe of the SSS and the distance between central and flanker stripes of the SSS were systematically varied across 12 experimental conditions (3 widths X 4 distances). Training. Subjects completed 300 trials of a speeded reaching task, in which they touched an SSS target on a touchscreen within 400 milliseconds. Task. On each trial, subjects judged which of two targets, an SSS or an S, was easier to hit. We used a staircase method to estimate the width of the S the subject judged to be as easy to hit as each of the 12 SSS targets. We tested three nested models: the true Gaussian, a Gaussian with a free variance, and a heavy-tailed t-distribution. Ten naïve subjects participated. Results: (1) The true error distribution of all the ten subjects was Gaussian in the horizontal direction. (2) Most subjects overestimated the probability of hitting parts of the target distant from the aim point. (3) Among them, the implicit distributions of 3/10 subjects were Gaussian of a larger variance than their true distributions. (4) The implicit distributions of 4/10 subjects were heavier-tailed than Gaussian.

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34.23, *3:00 pm*

Systematic biases occur when variability is compared across early and late portions of grasp trajectories

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Finding the variability of the maximum grip aperture (MGA) to be independent of object size, Ganel and Goodale (2003) suggested that the motor system does not follow Weber's law. Others asked whether this claim can be generalized to the unfolding of the grasping movement (Heath, Mulla, Holmes, & Smuskowitz, 2011; Holmes, Mulla, Binsted, & Heath, 2011; Holmes, Mulla, Smuskowitz, & Heath, 2011) and tested whether the variability of the grip aperture (aperture-variability) depends on object size at different time points of the movement. Because they found such a dependence for early but not late time points, they concluded that Weber's law holds only for early stages of a movement and grasping is controlled by two different processes. We suggest that this reasoning is based on an ill-specified null hypothesis. The dependence of aperture-variability on object size at early time points can be fully explained by the fact that, as movement time is roughly constant, the fingers must open faster for large objects than for small objects. This faster opening corresponds to a larger first derivative of aperture with respect to time (aperture-velocity). We show that aperture-variability is approximately proportional to aperture-velocity (more specifically: proportional and low-pass filtered). Therefore, even if we assume a perfectly unitary motor process that does not obey Weber's law at the time of the MGA, it will exhibit a pattern that resembles Weber's law for earlier time points (i.e., aperture-variability will depend on object size because aperture-velocity depends on object size). This effect is not solved by time normalization, which alters the apparent aperture-velocity by compressing and stretching trajectories. While motivated by a single line of studies, our observations show that it is inherently difficult to compare variance calculated for different time points in the grasping movement, and thus impact the interpretation of many time-dependent analyses in our field.

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34.24, *3:15 pm*

Internal Models for Predictive Saccades In a Natural Interception Task

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In the natural world, the brain must handle inherent delays in visual processing. One compensatory strategy is to combine prior experience with current sensory data to predict a future visual state. Although prediction is known to occur in both saccadic and pursuit eye movements, the factors that contribute to prediction are poorly understood. Furthermore, because most experiments have investigated 2D planar movements with restricted head-movements, it is unclear how the findings generalize to more natural environments. In this study, subjects intercepted virtual balls in a simulated environment seen through a head-mounted display. On each trial, a launched ball bounced on the floor before its arrival at the subject. The subject used a racquet to hit the virtual ball at a target on the far wall. We varied the velocity of the balls from trial to trial, and the elasticity of the ball between blocks of trials. On 83% of the trials, subjects initiated a saccade prior to the bounce, to a location 8˚ to 13˚ above the bounce-point. This location predicted the ball's post-bounce trajectory with high accuracy, so that the ball passed within 3.5˚ of the gaze point (+/- 0.53˚ SEM between subjects). The targeted location compensated almost exactly for the changes in trajectory resulting from ball velocity and elasticity, and the ball passed through the predicted location 141 (+/- 8) ms after the bounce in all conditions. This constant-time strategy meant that saccade height scaled linearly with predicted post-bounce ball velocity, suggesting that subjects used learnt knowledge of ball dynamics to predict where the ball would be after the bounce, and when it would get there. The accuracy of the prediction implicates a complex internal model of ball dynamics that accounts for changes in ball elasticity, 3D velocity, angle of incidence, and gravity.

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34.25, *3:30 pm*

Multiple coordinate frames for reaches revealed through adaptation

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In what coordinate system are visually guided reaches encoded? We introduce a novel, sensitive method for measuring the adaptive response to reach feedback perturbation, and provide evidence that both polar and Cartesian coordinate systems are used, because adaptive responses can be made to both polar and Cartesian perturbations. Methods: Subjects made center-out reaches on a tabletop with fixed starting point and target distance, with target direction random over trials. Starting point, target, and reach endpoint feedback were shown on a frontoparallel display. During the reach, only the target was shown. After reach completion, fingertip location was shown shifted spatially. The amount of shift was a sinewave over trials. For Cartesian perturbation, on trial t, xdisplay = xfinger + A sin(2πfxt) and similarly for y perturbed with frequency fy. For polar perturbation, gain of displayed relative to actual reach extent was perturbed around 1.0 with a sinewave of frequency fγ and reach direction was perturbed at frequency fθ. For Cartesian, fx=5 and fy=7 cycle/session; A = 6 mm. For polar, the same frequencies were used, and amplitudes were set to achieve similar maximum perturbations. Bayesian methods were used to detect sinusoidal corrections in response to perturbation and to estimate parameters. Results: Under Cartesian perturbation, subjects corrected for both x and y perturbations; under polar perturbation, independent correction of gain and direction was found. In addition, correction was found for reaches to targets at which feedback was never given. Thus, observers could adapt using either coordinate system, as appropriate. The sinewave-perturbation technique provides a far more sensitive technique for measuring adaptation than the typical step-function technique, allowing the use of perturbations so small that subjects are not consciously aware of them.

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34.26, *3:45 pm*

The influence of optic flow on control of walking gradually increases over the course of a movement

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Different heading-based strategies could be used to guide walking to a target. Observers could potentially align the visual direction of the target with their physical direction of movement, or their visual heading from optic flow, or some integrated estimate of heading. I investigated the relative influence of visual and physical heading on control of walking, and how this varies over the course of a movement. Previous studies have distinguished control strategies using conditions in which the visual heading specified by optic flow differs from an observer's physical direction of motion. I tested similar conditions but used a novel analysis to estimate the controller's goal state at different moments in time. Observers walked to a target pole in a virtual environment presented with a head-mounted display. On perturbed trials, visual heading differed from physical heading by ±10°. The target appeared after observers walked 1m in a pre-cued direction, and was randomly positioned in a range around the initial direction. I analyzed how path corrections across a brief time window depended on the current heading error relative to the target. Across a given time delay, change in heading was an approximately linear function of heading error. By fitting this function, one can estimate the heading error that would produce no steering adjustment across a time window. This goal state was estimated for 250 ms windows starting at target onset. Initial steering adjustments on perturbed trials were consistent with a goal state of aligning the physical heading direction with the target. Over the course of 2 s of walking, the estimated goal state gradually shifted to be approximately midway between the physical and visual heading. These results are consistent with control based on an integrated estimate of heading, which is initially determined by non-visual information but gradually incorporates heading information from optic flow.

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34.27, *4:00 pm*

Visually-guided reaching movements in depth: spatial tuning of single cell activity in the in monkey superior parietal area V6A.

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The superior parietal lobule (SPL) is strongly involved in organizing arm actions in space. Despite neuropsychological studies reported that patients with SPL lesions show deficits in reaching targets in depth, so far only few single cell recording studies addressed this issue. Cortical area V6A, located in the SPL of primates, carries signals related to the distance of targets from the eyes, and contains neurons with arm movement-related activity. Recent neurophysiological studies show that area V6A integrates, often at single cell level, vergence with gaze direction signals, thus encoding spatial location in 3D space (Hadjidimitrakis et al., Plos One 2011). The aim of present study was to examine the spatial encoding of single V6A neurons during fixation, preparation, and execution of reaches towards foveated visual targets in depth. Single unit activity was recorded in two macaque monkeys performing a visually-guided reaching task in darkness. Animals were required to fixate and reach targets (LEDs) placed at different positions and depth in 3D space. In the majority of cells, a significant effect of both target direction and depth was found in all time epochs. Spatial modulations were generally maintained from fixation through subsequent task epochs, till reaching execution. Spatial encoding was remarkably consistent across epochs, with common preferences evenly distributed in 3D space. Given the functional properties of V6A neurons, we suggest that this spatial information is integrated with somatosensory input coming from the upper limbs, to define and control the part of space that can be reached by the hands. These new findings demonstrate that, in an area involved in reaching and grasping (Fattori et al., Eur. J. Neurosci 2005; Fattori et al., J. Neurosci 2010), the encoding of action in 3D space is accomplished through the interaction of a variety of signals.

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Multisensory processing

Sunday, May 13, 5:15 - 6:45 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Maggie Shiffrar

35.11, *5:15 pm*

Impact of early versus late acquired blindness on the functional organization and connectivity of the occipital cortex

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Recent studies demonstrated that auditory processing in the reorganized occipital cortex of congenitally blind (CB) humans maintains some level of specialization that is known to characterize the occipital cortex of sighted individuals. A crucial yet unresolved question concerns the existence of a sensitive period in order for such specific reorganization to occur. Therefore, we investigated the impact of early versus late visual deprivation in shaping the functional properties of the occipital cortex. Using functional magnetic resonance imaging (fMRI), we characterized brain activations of CB and late blind (LB) subjects when they processed either the pitch or the spatial attributes of sounds. Our data demonstrates massive recruitment of occipital regions for auditory processing in both blind groups relative to matched sighted groups, although the extent was less widespread in LB when compared to CB. Intriguingly, some auditory activity in the occipital cortex observed in LB was inversely proportional to blindness duration. We also observed that some regions of the right dorsal stream (lateral occipito-temporal and cuneus) were preferentially activated for the spatial processing of sounds in CB only. This suggests that vision has to be lost during an early sensitive period in life in order to transfer its functional specialization for space processing toward a non-visual modality. Finally, dynamic causal modeling revealed that different architectures of cortical pathways underlie auditory activity in primary occipital cortex of CB and LB. Altogether, these results demonstrate important quantitative and qualitative changes in the cortical reorganizations observed in the CB and LB, unraveling the critical role of early versus late experience in shaping the functional architecture of the occipital cortex. These results are clinically important now that a growing number of therapeutic interventions may restore vision after a period of visual deprivation.

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35.12, *5:30 pm*

When correlation implies causation in multisensory integration

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Inferring which signals have a common underlying cause, and hence should be integrated, represents a primary challenge for a perceptual system dealing with multiple sensory inputs. This challenge is often referred to as the correspondence problem or causal inference. Previous research has demonstrated that spatiotemporal cues, along with prior knowledge, are exploited by the human brain to solve this problem. Here we explore the role of correlation between the fine temporal structure of auditory and visual signals in causal inference. Specifically, we investigated whether correlated signals are inferred to originate from the same distal event and hence are integrated optimally. In a localization task with visual, auditory, and combined audiovisual targets, the improvement in precision for combined relative to unimodal targets was statistically optimal only when audiovisual signals

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were correlated. This result demonstrates that humans use the similarity in the temporal structure of multisensory signals to solve the correspondence problem, hence inferring causation from correlation.

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35.13, *5:45 pm*

The temporal resolution of binding brightness and loudness in dynamic random sequences

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Purpose. This study investigated the ways in which observers can combine dynamic visual and auditory information. Method. The stimuli were composed of gray disks accompanied by simultaneous bursts of auditory white noise. Three levels of disk brightness and of noise loudness were used to produce 9 different types of audiovisual tokens. On a given trial, 18 tokens (83ms per token) drawn from these 9 token types were presented in random order. Different conditions required participants to try to classify stimulus sequences using various target filters that gave differential weight to the 9 audiovisual token types. In each condition, a probit model was used to measure the attention filter achieved by the participant (the impact exerted on the observer's judgments by each of the 9 token-types). The model also included terms reflecting potential non-simultaneous "misbindings" across time of auditory and visual components. Results. Participants demonstrated a high degree of strategic flexibility in achieving attention filters that varied widely across tasks, but these filters often deviated strongly from the corresponding target filters. Model fits revealed that misbindings of auditory and visual components that were 83 ms apart influenced judgments with half the strength of simultaneous components. Components that were 167 ms apart did not misbind. Conclusions. The temporal resolution of the binding achieved with these stimuli is higher than is found in tasks requiring the observer to judge the phase with which an alternating pair of visual stimuli matches up with an alternating pair of auditory stimuli (Fujisaki & Nishida, 2010). In correlating loudness and brightness, the space of attention filters that participants are able to achieve is at least three dimensional. Citation: Fujisaki, W & Nishida, S (2010). A common perceptual temporal limit of binding synchronous inputs across different sensory attributes and modalities, Proceedings of the Royal Society of London B: Biological Sciences,277(1692):2281-90.

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35.14, *6:00 pm*

An invisible face facilitates speech perception

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It has been shown that looking at moving lips facilitates speech perception. This facilitation, however, occurs only when the mouth is attended. Recent evidence suggests that visual attention and awareness are mediated by separate mechanisms. We therefore investigated whether visual facilitation of speech perception required awareness of lip movements. We used a word categorization task in which participants listened to spoken words and determined as quickly and accurately as possible whether each word indicated a tool. While the participants listened to the words they saw the face of the speaker that articulated either the spoken word — the synchronous condition, or a different word of the same length — the asynchronous condition. Critically, the speaker's face was either fully visible — the aware trials, or suppressed from awareness using Continuous Flash Suppression where the face was presented to one eye and a strong dynamic mask was presented to the other eye — the suppressed trials. The aware and suppressed trials were randomly intermixed. A dot-detection task was used to ensure that participants attended to the mouth region whether the face was visible or suppressed. A small fraction of the suppressed trials on which the face broke through into awareness were removed from the analysis. On the aware trials responses to the tool targets were no faster with the synchronous than asynchronous lip movements, probably because participants discarded the visual information for being inconsistent with the auditory information on 50% of the trials. However, on the suppressed trials responses to the tool targets were significantly faster with the synchronous than asynchronous lip movements. These results demonstrate that even when a random dynamic mask renders a face invisible, lip movements are still unconsciously processed by the visual system with sufficiently high temporal accuracy to facilitate speech perception based on crossmodal synchrony.

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35.15, *6:15 pm*

Seeing the song: Left auditory cortex tracks auditory-visual dynamic congruence

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Part of the beauty of watching a ballet is the synchrony or dynamic congruence between what we see and what we hear. It is already known that in humans, the left primary auditory cortex processes complex auditory dynamics when sounds are presented alone, but it is not clear whether the brain exploits this specialization for use in encoding cross-modal dynamic congruence. Here we report the results of an EEG experiment in which auditory and visual stimuli sharing complex dynamics across multiple feature dimensions and scales (Beethoven's Moonlight Sonata and the iTunes Jelly visualizer) were presented to 28 participants in a temporally congruent condition (visualizer matched music) and also an incongruent condition (visualizer delayed by ~30 seconds). Condition order was counterbalanced across participants, and only ~30% of the participants detected the difference between the conditions. We used continuous auditory steady-state responses (ASSR) combined with current-source density (CSD) mapping to pinpoint auditory cortical activity tuned to the music. As expected based on previous work, right hemisphere ASSR power dominated in both conditions. More importantly, an interaction between hemisphere and congruence ($p<0.035$) revealed that when the music and visualizer were temporally incongruent, the left hemisphere had significantly lower steady-state power than the congruent condition ($p<0.007$). ASSR power arising from the same musical stimuli recorded from the same participants while they performed two separate attentionally demanding visual tasks did not differ from the congruent condition, suggesting that the drop in power in the left hemisphere during the incongruent condition is not due to a difference in auditory attention, but is a reflection of the encoding of dynamic congruence between the music and images. These results show that left primary auditory cortex encodes auditory-visual dynamic congruence and thus contributes to the binding of concurrent auditory and visual stimuli based on complex temporal cues.

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35.16, *6:30 pm*

Audiovisual action priming: meaning, time, and signal strength

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The integration of multisensory information depends upon spatial and temporal coincidence, signal strength, and semantics (Meredith & Stein, 1983; Welch & Warren, 1986). Sounds also aid visual detection. Visual sensitivity to human actions improves when paired with sounds that are both semantically and temporally congruent (e.g. Arrighi et al., 2009). Two studies investigated the roles of meaning, timing, and visual signal strength in visual sensitivity to human actions. Experiment 1 tested whether temporal synchrony is necessary for meaningful sounds to impact visual sensitivity. Participants performed a point-light walker detection task with sounds that were meaningful (footsteps) or neutral (tones) and synchronous or asynchronous with point-light footfalls. Results revealed a main effect of sounds, no effect of synchrony, and no interaction. Sensitivity with both coincident and random footsteps was significantly greater than sensitivity with temporally coincident tones or temporally random tones. This suggests that audiovisual action priming occurs at the level of meaning and that sounds can enhance visual sensitivity in the absence of temporal coincidence (e.g. Schneider et al., 2008). Experiment 2 investigated whether signal strength moderates the effect of meaningful sounds on the priming of visual actions, as predicted by the multisensory rule of inverse effectiveness (IE) (e.g. Collignon et al., 2008). Participants detected a point-light walker in a mask of varying densities that rendered detection more or less difficult. Results revealed a main effect of sounds, but no interaction between sounds and mask density; footsteps improved sensitivity across all levels of mask density. However, when the data were analyzed according to walker detection accuracy in silent displays (Thomas & Shiffrar, 2011), an interaction emerged, such that footstep sounds improved sensitivity for visually difficult movies. These results agree with the IE rule. When an action is difficult to perceive, a related sound can facilitate visual detection.

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Decision making and reward

Sunday, May 13, 5:15 - 6:45 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Matteo Carandini

35.21, *5:15 pm*

Time to decide: sampling based representation of uncertainty in human vision

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Growing behavioral evidence suggests that animals and humans represent uncertainty about both high and low-level sensory stimuli in the brain for probabilistic inference and learning. One proposal about the nature of the neural basis of this representation of uncertainty suggests that instantaneous membrane potentials of cortical sensory neurons correspond to statistical samples from a probability distribution over possible features those neurons represent. In this framework, the quality of the representation critically depends on the number of samples drawn, and hence on the time available to perform a task. This implies a strong link between the available time and the reliability of the representation. We tested this hypothesis in an orientation matching experiment with two distinct types of stimuli: circles consisting of 1-4 Voronoi patches, each filled in with a number of gray-scale Gabor wavelets with their orientations sampled from a Gaussian distribution with a different mean orientation; and 2-10 differently oriented line segments spaced evenly on a circle. After 2 seconds of stimulus presentation subjects were asked to match the orientation of one of the patches or lines in the stimulus, and indicate their certainty about the correctness of the orientation match. To test our predictions, we manipulated the number of samples on a trial-to-trial basis by varying the time available to respond. Without time constraints, subjects' performance and certainty judgment were significantly correlated independent of the number of patches or lines the stimuli consisted of. With a decrease in available time, subjects' orientation and certainty judgments followed the theoretically predicted trends. Importantly, a decrease in response time lead to a decrease in correlation between performance and uncertainty, even though the performance remained unchanged. Therefore, limiting the response time, and consequently the number of samples drawn, significantly influences the quality of uncertainty representation in accord with the sampling hypothesis.

35.22, *5:30 pm*

Direct injection of neural noise leads to double dissociation between accuracy and confidence

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The relationship between accuracy and confidence in psychophysical tasks has traditionally been assumed to be mainly positive, i.e. the two typically increase or decrease together. However, recently we showed that spatial attention can lead to dissociations between visual sensitivity and confidence ratings (Rahnev et al., 2011, Nature Neuroscience). The data were explained by a computational model in which lack of attention increased the variability of the internal distributions. In order to test this model, we directly injected neural noise by applying transcranial magnetic stimulation (TMS) to the occipital cortex. We expected TMS to increase the variability of the internal response and, in a similar fashion as in inattention, lead to decreased accuracy but increased confidence. In our task, subjects discriminated between left- and right-tilted bars and simultaneously received single TMS pulses at SOA of 100 ms. Compared to TMS applied to a control site (vertex), occipital TMS led to significantly lower accuracy ($p = .007$) but significantly higher confidence ($p = .01$). This striking double dissociation provides strong support of our variance-based model. To confirm that the increased variability of the signal was indeed the key reason for the dissociation, we performed a formal model comparison analysis that used information theoretic methods. The analysis confirmed that our model was preferred over models in which TMS changed the signal strength or "dual-channel" models that postulate two processing streams. These results imply a central role of neural variability in perceptual decisions (Cohen and Maunsell, 2009) and suggest that confidence ratings may be produced by a highly suboptimal decision mechanism.

35.23, *5:45 pm*

Active visual sampling in uncertain environments

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Eye movements serve to gather information from the environment. Typically, stimuli cannot be sampled in parallel, meaning we only gain knowledge about the currently sampled source of information. We examined whether, given limited time to inspect a number of sources of noisy information, the time allocated to each source is adapted to the level of uncertainty in both the environment and sensory signals. Observers performed a relative motion direction discrimination judgement between two random dot kinematograms (RDKs). Motion information was only delivered when gaze was fixed on a pattern. Low and high coherence patterns were paired independently, but when the coherence of the two patterns differed, the more noisy source should be inspected for longer. In one condition, the mapping between dot polarity and coherence was random: when inspecting the first pattern, the noise level in the second pattern was unknown. In a second condition, the coherence was consistently mapped onto the polarity of the RDK dots and observers have perfectly reliable information about the sensory noise they will encounter. In this case, we expected more complete adaptation of sampling time to the noise levels, matched to the precision of the underlying internal direction estimates. Observers sampled the patterns adaptively, but there was no difference in the extent of adaptation under random and consistent mappings: observers ignored the available information about the noise in the information sources. In a second experiment, we provided this information further in advance, but sampling behaviour remained unaffected. The degree of adaptation was smaller than expected based on independent measurements of the precision in the internal sensory direction estimates. We conclude that observers based their gaze allocation solely on the uncertainty of the first source they inspected. The sampling strategy was not adjusted to the global level of (un)certainty about the environment.

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35.24, *6:00 pm*

A new 2AFC method for the comparison of stimuli that differ along multiple stimulus dimensions

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2AFC methods are frequently used to assess the influence of a secondary stimulus parameter (e.g. stimulus noise) on the percept of a primary stimulus dimension (e.g. motion direction). In this case, test and reference not only differ along the primary stimulus dimension, but also in their value of the secondary stimulus parameter. As a result, even a thorough instruction does not guarantee that a subject's choice is exclusively based on the perceived differences along the primary stimulus dimension. This can lead to an incorrect characterization of perceptual biases and thresholds. We present a new 2AFC method that prevents this problem by using two reference stimuli instead of one. On each trial, the test and the two reference stimuli are simultaneously presented, and the subject has to choose the reference that is perceptually closest to the test. Because the choice is between the two references (as opposed to reference and test), the decision can only be based on the perceived difference along the primary stimulus dimension, thus avoiding any potential confounds in the decision process. We can formulate an observer model for our new method based on standard signal detection theory. It allows us to extract the point-of-subjective-equal-

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ity as well as the noise widths for both references and test independently. An adaptive staircase procedure based on a continuous entropy measure allows the efficient allocation of trials within the experimental parameter range. Numerical tests confirmed both, convergence and efficiency of the new method. Finally, we applied the new method to a random-dots motion discrimination experiment, characterizing perceived motion direction (primary dimension) for different dot coherence levels (secondary parameter). Subjects showed no problems to perform the task. Model fits well capture subjects behaviors, and the extracted noise widths correctly reflect the coherence levels, thus demonstrating the practicability and validity of our new method.

35.25, *6:15 pm*

Vision and Superstition in Mouse and Man

Matteo Carandini[1], Laura Silva[1], Laura Busse[1], Steven Dakin[1]; [1]UCL Institute of Ophthalmology, University College London

When performing a purely visual task such as contrast detection, any strategy based on nonvisual factors will lead to suboptimal performance. We recently found such suboptimal behavior while probing the mouse's visual capabilities in a two-alternative forced choice experiment (Busse et al. Journal of Neuroscience, 2011). Daily sessions in mice yielded high-quality psychometric curves for contrast detection, with hundreds of trials. Although the stimulus could appear, with equal probability, on the left or right of the display, mice rarely acted as if the stimulus location was random: their choices depended on estimates of reward value and on "superstition" factors such as recent failures and rewards. This behavior was captured by a simple generalized linear model involving superstition terms depending on the outcome of the previous trial. These terms often had more weight than a 20% contrast grating on the subsequent decision. Is this superstitious behavior limited to mice? We performed similar experiments in humans (rewarding them with a sound rather than a drop of water), and found to our surprise that very similar superstitious effects shape human psychometric curves. Human observers give particularly strong negative weights to past failures, and they often extend their superstitious weighting of nonvisual factors to events occurring in the past two or three trials. Once again, a generalized linear model was very effective in predicting all these effects. This superstitious behavior is likely affecting many a published psychometric curve. It masquerades as noise that limits sensitivity. Knowing about it and accounting for it with a simple model can be useful for multiple reasons: (1) it allows for much cleaner estimates of psychophysical sensitivity; (2) it might be used to defeat superstition by devising appropriate stimulus presentation schedules; (3) it allows the study of the superstition influences, both in psychophysics and in neural recordings.

Acknowledgement: Medical Research Council, European Research Council

35.26, *6:30 pm*

Reward learning increases visual salience

Jan Theeuwes[1](J.Theeuwes@psy.vu.nl), Artem Belopolsky[1], Erik Van der Burg[1]; [1]Vrije Universiteit Amsterdam

Several recent studies have shown that physically nonsalient stimuli associated with value through reward learning may affect attentional selection. One of the prominent hypothesis is that reward learning converts a stimulus with a neutral representation into a salient, 'wanted' stimulus. In the current study we provide direct evidence for this hypothesis. During the training phase, observers searched for a red or green target among differently colored nontargets. On each trial, following a correct response, they received feedback indicating a monetary reward which for one of the two target colors was associated with a high reward and for the other color with a low reward. Subsequently, in the test phase, observers were asked to perform an unspeeded simultaneity judgment (SJ) task, in which they indicated whether two visual stimuli (i.e. the red and green from the training phase), presented on either side of fixation, were presented simultaneously or not. The results showed that in order for the two stimuli to be perceived as simultaneous, the stimulus that was associated with a low reward had to be presented before the stimulus that had been associated with a high reward. This result provides compelling evidence that reward changes the salience of the stimulus and thus the temporal order of the two stimuli. Note that the results can not be explained by a response bias.

 See page 3 for Abstract Numbering System

Face perception: Wholes, parts, configurations, and features

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

36.301 An adaptation study of internal and external features in face representations

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Background: Previous studies have shown observers rely more on internal than external features when recognising familiar but not unfamiliar faces. Objective: We used an adaptation paradigm to examine whether this difference in internal and external feature contributions to processing is also reflected in differences in the representations of these two classes of faces in the human visual system. Methods: Twelve subjects adapted to a) whole faces, b) internal features alone, or c) external features alone for 5sec, and were then asked whether a briefly shown ambiguous whole-face most resembled the first or second person. Ambiguous faces were created by morphing between pairs of faces. One set of blocks used four pairs of celebrities, while the other used four pairs of anonymous faces. Results: We replicated the finding of face-identity aftereffects with whole face adaptors, with equivalent magnitude for both familiar and unfamiliar faces. For unfamiliar faces, adaptation to internal features alone and to external features alone also generated face aftereffects in whole-face test images, which were similar in magnitude but less than that from whole-face adaptors. However, for familiar faces, identity aftereffects were produced only by whole-face adaptors and not by internal or external features in isolation. Conclusion: Internal and external features are equivalent in perceptual representations of unfamiliar faces. Familiar faces require the whole-face context for access to their representations, which may reflect another characteristic of holistic mechanisms in face processing.

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36.302 Top and bottom half faces influence equally and interact nonlinearly in face-identity adaptation

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We have shown that a whole face can produce a significantly larger facial-expression aftereffect than the linear summation of the aftereffects induced by face parts – the mouth alone and a mouth-less face – suggesting that face parts interact nonlinearly in facial-expression adaptation (Xu, et al., 2011). The current study investigates whether and how face parts interact nonlinearly in face-identity adaptation. We split a real face (“Adam”) into two size-equivalent face parts, the top-half and the bottom-half faces. We used these half faces and the whole face as the adaptor in separate conditions. For the test stimuli, the whole “Adam” face was morphed with another identity’s whole face (“Sam”). The proportion of “Adam” varied from 0% (original “Sam”) to 100% (original “Adam”). In each trial, observers viewed the adaptor for 4 s, and after a 500 ms inter-stimulus interval viewed a test face for 200 ms. Observers then indicated the perceived face identity of the test face (“Adam” or “Sam”) via a key press. They were also tested in a baseline condition without adaptation. The face-identity aftereffects for the three adaptors were measured as shifts of the psychometric curves from the baseline condition. We found that both top-half and bottom-half faces generated significant face aftereffects of similar magnitude. Moreover, the whole-face adaptation aftereffect is significantly larger than the sum of the aftereffects produced by the top-half face and the bottom-half face. This finding suggests a nonlinear interaction among the two half faces in face-identity adaptation. Such nonlinearity indicates a holistic nature in face identity processing, and is consistent with physiological and computational studies that show high-level areas combine low-level features nonlinearly along the visual hierarchy.

36.303 Exploring the relationship between the N170 inversion effect and horizontal tuning

Ali Hashemi[1](hashea@mcmaster.ca), Matthew V. Pachai[1], Patrick J. Bennett[1,2], Allison B. Sekuler[1,2]; [1]Department of Psychology, Neuroscience, and Behaviour, McMaster University, [2]Centre for Vision Research, York University

Recent research suggests that faces contain the most information in the horizontal orientation band (Dakin & Watt, J Vis 2009), and the size of the behavioural face inversion effect (bFIE) is correlated with changes in horizontal tuning following inversion (Pachai et al., VSS 2011). Moreover, ERP studies have shown that 1) the N170 is delayed and sometimes increased in amplitude following inversion, 2) the N170 and bFIE are correlated (Jacques and Rossion, NeuroImage 2007), and 3) the N170 inversion effect decreases when horizontal information is scrambled (Jacques et al., VSS 2011). However, the question remains whether the N170 is associated with horizontal tuning, and how that association varies with face inversion. To answer these questions, observers completed a 10AFC identification task using filtered faces. In the full-face condition, faces contained information at all orientations. In the horizontal/vertical conditions, target face information was contained only in orientations within ±35 deg of horizontal/vertical; remaining orientations contained non-informative face information, so stimuli were face-like in all conditions. Initial results from 8 observers, show a bFIE only in the full-face and horizontal conditions. N170 latency, but not amplitude, depended on both orientation filtering and face orientation. Specifically, face inversion increased latency equivalently across filter conditions, whereas latency for upright faces depended on orientation filtering, with the shortest and longest latencies occurring in the full-face and vertical conditions, respectively. When we examined the relationship between the N170 inversion effect for full-faces and the change in behavioural horizontal tuning (horizontal – vertical) following inversion, we found a positive correlation for both latency ($r=0.78$) and amplitude ($r=0.56$). To date, our findings reinforce the notion that upright face identification is driven by increased efficiency in processing horizontal face information compared to vertical, and suggest an association between changes in this efficiency following inversion with changes in the N170.

Acknowledgement: Canada Research Chair program and NSERC

36.304 Reduction of the perceptual field for inverted faces: evidence from gaze contingency with full view stimuli

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Selective gaze-contingent masking of the fixated feature in face recognition increases the processing difficulty for inverted, compared to upright faces. Preventing the use of peripheral information by revealing only the fixated feature through a gaze-contingent window, however, results in a decreased inversion effect (Van Belle et al., JOV, 2010). This suggests that the inversion effect is caused by problems in simultaneously perceiving multiple facial features present outside of the fixated feature, for inverted faces. However, gaze contingent masking or windowing explicitly forces human observers to change their processing strategy. Here we aimed at directly observing the differential use of fixated (central) and peripheral information in upright/inverted faces, without manipulating the processing strategy. Therefore, we conducted a matching task in which each trial consisted of three simultaneously presented faces in full view (Figure 1). Participants’ task was to indicate which of two faces presented side by side on the lower half of the screen resembled most the reference face in the top part of the screen. The reference face, however, consisted of a combination of both bottom faces in a gaze contingent way. The part of the reference face in the center of gaze equaled the corresponding part of one of both alternative faces. The remaining part of the reference face equaled the remaining part of the other answering alternative. The reference face was therefore updated upon each gaze position shift. Although the overall preference for choosing the central or peripheral face differed considerably between participants, the proportion of choices for the answering alternative corresponding to the centrally presented part of the reference face was significantly and consistently higher for inverted than for upright faces. These observations confirm the narrower perceptual field for inverted than for upright faces, supporting a more holistic processing strategy for upright than for inverted faces.

36.305 **The role of symmetry in the efficiency of detecting, discriminating and identifying human faces**

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The presence of symmetric properties in a stimulus has been thought to often exert an influence on perception and information processing (e.g., Koffka, 1935; Kohler, 1947; Tyler, 2002). Investigations in this field have given rise to the general notion that symmetry is processed easily and efficiently by the human visual system (e.g., Little & Jones 2003; Scognamillo, Rhodes, Morrone, & Burr, 2003). However, only a handful of studies have attempted to actually measure the role that symmetry plays in the efficiency of information use (e.g., Barlow, 1979; Liu & Kersten, 2003). In our experiments, we explored the impact of symmetry within the area of face perception, a domain where symmetry has been thought to play a particularly important role (e.g., Epley & Whitchurch, 2008; Little & Jones, 2003; Onionen & Mazmanian, 2007; Wilson, Wilkinson, Lin, & Castillo, 2000). Specifically, we measured information processing efficiency, defined as the performance of a human observer relative to that of an ideal observer, for the detection, discrimination, and identification of symmetric and asymmetric versions of unfamiliar male and female faces. We found no evidence for significant differences in efficiency between asymmetric and symmetric conditions within all three of our paradigms, with analogous results across the genders of our face stimuli and the genders of our participants. We conducted a second experiment that was designed to explore the possible influence of learning and familiarity on relative efficiency for symmetric and asymmetric faces. Although training yielded significant improvements in absolute efficiency, it had no significant effect upon the relative efficiency between asymmetric and symmetric faces. Our results indicate that, although symmetry may play an important role in other aspects of face perception (e.g., perceived beauty), it has no discernible impact upon the efficiency with which information is used when detecting, discriminating, and identifying faces.

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36.306 **Influences of Familiarity on the Face-Inversion and Other-Race Effects**

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Introduction: The current study asked whether face discrimination abilities differ for unfamiliar vs. familiar faces and whether familiarity influences the face-inversion and the other-race effects. Methods: The stimuli were pictures of faces of females (East Asian and Caucasian) from two different labs. Subjects were twenty-five females of East Asian or Caucasian descent from the two labs. This resulted in two groups of participants who were tested with the same stimulus set, yet different assignments of familiar vs. unfamiliar, as well as different assignments of same-race vs. other-race. The face discrimination task consisted of participants indicating whether a test face, presented for 500 ms, was more similar to one of two sample faces presented simultaneously after the test face. Sample faces were pairs of faces of the same race and lab. Test faces were morphed stimuli that varied in 100 even step sizes from 100% Sample Face A to 100% Sample Face B. Threshold was defined as the average of two thresholds: % Sample Face A (and B) needed to correctly match the morphed test face to Sample Face A (and B) on 80% of trials. Threshold was obtained for each of eight conditions: Races (same/other) x Familiarity (familiar/unfamiliar) x Orientation (upright/inverted). Results: An ANOVA revealed superior performance on familiar vs. unfamiliar faces ($p<0.05$) and an interaction between familiarity and orientation ($p=0.05$), which was driven by a greater inversion effect for familiar faces ($p<0.05$). No statistically significant other-race effects were found; however, there was a trend for a smaller effect of race for familiar upright than unfamiliar upright faces. Conclusions: Inversion effects are greater for familiar faces, which may be due to familiar faces being processed more holisticly than unfamiliar faces. Further work will be needed to ascertain whether familiarity mediates the other-race effect.

36.307 **The Role of Attention in Face Perception: Cuing to Spatial Location versus Type of Information**

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Since all faces share the same set of features that are arranged in a common configuration, face perception must depend on our ability to discriminate between subtle differences in the features and the distances between them. To gain insight into the face information that is of greater importance in the discrimination process, we look at the face inversion effect. Recent research has demonstrated that inversion produces a selective impairment of the mouth region. The current study aimed to test the hypothesis that the selective mouth impairment is caused by a lack of attentional resources. Towards this goal, we employed the Face Dimensions Test where the featural and configural properties in the upper and lower regions of a face were parametrically manipulated. Configural information was modified by varying either the distance between the eyes or the distance between the nose and mouth. Featural information was manipulated by either scaling the size of the eyes or mouth features. Discriminability was equated across the four dimensions (eyes-featural, eyes-configural, mouth-featural and mouth-configural) in faces shown in their upright orientations and tested in their inverted orientation. Participants were tested in a same/different task. Whereas focused attention to the mouth region negated the inversion effect for both featural and configural information (Experiment 1), focused attention on type of information did not negate the mouth inversion effect (Experiment 2). The results suggest that attention plays a larger role in the mouth inversion effect. In upright faces, the attentional window covers the entire face allowing us to extract information from both regions of the face. In inverted faces, the attentional window diminishes and attention is focused on the eye region because of its salience. However, attention can be redirected to the mouth region, which allows extraction of information from this region.

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36.308 **Facial coding at isoluminance: Face recognition relies disproportionately on shape from shading**

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Human face recognition is disproportionately impacted by image rotation, becoming very difficult when an image is viewed upside down. The reasons for this remain a topic of heated debate. One factor might be that variations in three-dimensional (3d) structure are very important for facial coding. Inverting a facial image would therefore result in critical 3d shape from shading cues being viewed from an unfamiliar angle. Here we test this proposition via another manipulation, which eliminates 3d shape from shading cues altogether. We contrast peoples' ability to categorize cars and faces when images vary in luminance and when images only contain differences in colour (isoluminance, which eliminates all shape from shading cues). We find that isoluminance impairs performance disproportionately on a facial classification task relative to car classifications. This was true even though the two tasks were behaviourally matched for difficulty when images contained luminance differences. Nor could this effect be due to facial coding being selectively impacted by image blur at isoluminance, as performance dropped off equally for cars and faces as blur was added to images containing luminance differences. Our data therefore demonstrate that 3d shape from shading cues can be more important for facial coding than for analyses of other object categories.

36.309 **Recognition memory is more accurate when faces are inverted than when they are upright**

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The face inversion effect (FIE) indicates a dramatic impairment of recognition for upside-down faces (Yin, 1969). The FIE has been attributed to memory encoding, but it has also been found in the simultaneous presentation of face images (e.g., Farah, Wilson, Drain, & Tanaka, 1998). Here, we investigate the FIE by using perceptually matched upright and upside-down faces. Method. Experiment 1. Face continua were generated by morphing between two faces having different identities. A psychometric procedure was used to select pairs of morphed faces, either upright or upside-down, that produced 55, 65, 75, and 85% correct performance in a perceptual discrimination task (i.e., when two face images were simultaneously presented). In Experiment 2, the upright and upside-down face pairs, which had been found to be equivalent in terms of perceptual discriminability, were used in an old/new recognition memory paradigm. Results. Experiment 1: Equivalent levels of perceptual performance required larger morph distances for the upside-down faces than for the upright faces (this result replicates the face inversion effect). Experiment 2: Recognition memory performance was better for the upside-down than for the (perceptually matched) upright faces. The advantage of upside-down faces in recognition memory decreased with increasing perceptual dissimilarity between the memory and the probe image. Conclusions. When upright and upside-down faces are equally discriminable in a perceptual task, performance in memory recognition is better for the upside-down than for the upright faces. This result is the opposite than expected by the FIE. We discuss this finding in the light of the different principles that may underline the organization of upright and upside-down faces in the similarity face-space (Valentine, 1991).

36.310 **A face inversion effect without a face**

Talia Brandman[1](talli.brandman@gmail.com), Galit Yovel[1]; [1]Department of Psychology, Tel Aviv University

Numerous studies have attributed the face inversion effect (FIE) to configural processing of internal facial features in upright but not inverted faces. Recent findings suggest that face mechanisms can be activated by faceless stimuli presented in the context of a body. Here we asked whether faceless stimuli with or without body context may induce a face-sized inversion effect. In Experiment 1 subjects performed a sequential matching task for upright and inverted faces, faceless heads with full, minimal or no body context, headless bodies and bodies viewed from the back. The face stimuli differed in identity and were used to assess which of the other stimuli would generate a face-sized inversion effect. All faceless stimuli differed in posture. Our results show face-sized inversion effects for faceless heads with full or even minimal body context, but not for faceless heads without any body context, headless bodies or bodies viewed from the back. In Experiment 2 we briefly presented the same stimuli with or without faces followed by a mask and asked subjects to rate how confident they were that they saw a face in the image. We found high confidence rating for the existence of a face for the same faceless stimuli that generated a face-sized inversion effect, but low ratings for the faceless stimuli that generated a small inversion effect. These findings remarkably show that in contrast to the well-established configural explanation for the FIE, the FIE does not necessarily depend on the processing of internal facial features, but can be also triggered for faceless stimuli by the representation of a contextually induced face percept.

Acknowledgement: Israeli Science Foundation 65/08

36.311 **Classification image analysis reveals different cognitive strategies for symmetry and face processing**

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Introduction: Symmetry and face processing have some common characteristics, but they may rely on different cognitive strategies. Here we used classification image analysis (Eckstein & Ahumada, 2002) to determine subject's strategies, and to distinguish parts-based from holistic mechanisms. Methods: By manipulating face photographs, we created a library of 18 x 24-check binary (black and white) images in which symmetry and face-likeness varied independently. Subjects (N = 6) identified the target that was most symmetric among three distractors of equal face-likeness (experiment 1), and identified the target that was most face-like among three distractors of equal symmetry (experiment 2). Classification images were constructed by correlating the symmetry of each check-pair (i.e., whether the luminance of a check matched the luminance of its mirror reflection in the opposite half of the image) with the probability that the image was identified as the target. Results: Classification images based on check pairs showed that subjects employed different strategies for the two tasks, and for upright versus inverted faces. In experiment 1, the largest number of significant contiguous checks was in the eye region; the observed clusters would have occurred less than ~ 2% of the time by chance. In experiment 2, the largest cluster of contiguous checks was on the midline; a cluster this size along the midline would only occur ~ 4% of the time by chance. Conclusions: Task demands and image orientation both influenced the classification images, suggesting subjects relied on different holistic processing strategies for symmetry processing and face identification.

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36.312 **Navon effect on face recognition does not depend on eye movements**

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Introduction: There is a debate in the current literature on whether eye-movements influence holistic face processing (e.g., Schwarzer, Huber, & Dummler, 2005). Here, we investigate this issue by examining whether unrestricted eye-movements (free-viewing), on one side, and restricted eye-movements, on the other side, modulate the priming effects induced by a Navon task on an immediately successive face recognition task. Methods: In Experiment 1, participants underwent a training phase in which they were asked to judge a sequence of pairs of Navon stimuli, performing the Navon task at either the global level or the local level. In each trial of the successive experimental phase, participants were shown a Navon stimulus followed by two faces in rapid succession. The first face was shown for 500 ms whereas the second face remained on the screen until the participant's response. Participant performed the Navon task and then judged if the two faces were identical. The structure of trials in Experiment 2 was nearly identical, except that the second face image was presented for 300 ms only to prevent eye movements. Results: The global Navon task facilitated face recognition: When participants were asked to analyze the Navon letters at the global level, face recognition was faster than when participants were asked to analyze the Navon letters at the local level. We found no difference in the priming effects induced by the processing of Navon stimuli in the free-viewing condition (Experiment 1) and in the restricted eye-movements condition (Experiment 2). Conclusion: These results confirm that eye-movements do not represent a necessary requirement for global face processing (de Heering, Rossion, Turati, & Simion, 2008).

36.313 **Fine-grained sensitivity to vertical differences in triadic gaze is slow to develop**

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Adults use the direction of gaze toward objects in the environment (triadic gaze) to make judgments about the focus of a person's visual attention. Adults are able to detect horizontal and vertical differences of ~1° in the target of triadic gaze (Bock et al., 2008; Symons et al., 2004). Children's sensitivity to horizontal differences becomes adult-like around age 10, with a 50% increase in sensitivity after age 6 (Vida & Maurer, 2012). In Experiment 1, we used a child-friendly method to compare sensitivity to vertical differences between 6-, 8-, 10-, 14-year-olds and adults (n=18/age group). Participants viewed photographs of faces fixating a vertical series of points (separated by 1.6°) that were physically marked on a board between the observer and the monitor. Participants pressed a key to indicate whether a face appeared to be looking above or below a designated target position, which was positioned at the eye height of the model and observer or 6.4° above or below it. At age 6, thresholds were small (M=1.53°), but were larger than those of adults (M=.88°), p<.005. Thresholds did not decrease to adult levels until around age 14. All age groups displayed lower sensitivity for the upper target (M=1.37°) than the target at eye height (M=1.14°), p<.01, and an upward bias of ~1° for the upper and eye height targets, ps<.01. Experiment 2 indicated that at least some of the developmental change arises from children's lower sensitivity to vertical differences in eye position. Specifically, 8- (M=.73) and 10-year-olds (M=.76) were less accurate than adults (M=.83) at detecting vertical mismatches in the direction of gaze between simultaneously presented faces, ps<.002 (n=18/age group). These results indicate that until after age 10, children's judgments about the focus of others' attention are limited by insensitivity to vertical gaze cues.

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36.314 **Tests for Configural processing in the Thatcher Illusion**

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Thatcherisation of facial features is immediately apparent only in upright faces. Detection of Thatcherisation is therefore widely upheld as being dependent on configural processing. Configural processing has clear predictions of perceptual dependence between facial features and of supercapacity processing. Perceptual dependence: Configurality in General Recognition Theory (GRT, Ashby & Townsend, 1986) can be conceptualized in terms of violations of perceptual independence, in which the perceptions of the eyes and mouth of a single face are positively correlated; for example, the more inverted the eyes look, the more inverted the mouth will look. Participants were briefly presented with normal, partially Thatcherised and fully Thatcherised faces, and were asked to report whether the outline, eyes and mouth were upright or inverted. Consistent with the predictions, multidimensional probit models (DeCarlo, 2003) revealed that within-stimulus perceptual interactions occurred more frequently for upright than inverted faces. However, for the Thatcherised stimulus itself, there was no overall correlation between the eyes and the mouth, suggesting a lack of configural processing for this type of stimulus. Processing capacity: Supercapacity processing is predicted to accompany configural processing (O'Toole, Wenger & Townsend, 2001; Wenger & Townsend, 2001). Therefore, the detection of Thatcherised features in upright faces should be marked by supercapacity processing of inverted eyes and mouths relative to the inversion of only eyes or only mouths. Response times were used to compute measures of processing capacity (capacity coefficient, Townsend & Wenger, 2004; proportional hazards ratio, Wenger & Gibson, 2006) in Thatcherised upright faces. Results demonstrated limited evidence of supercapacity processing, and only in some individuals, implying that configural processing is not necessary for processing of upright Thatcherised faces. In summary, predictions from GRT and of processing capacity were tested across two separate studies, with little evidence found for perceptual independence or supercapacity processing for Thatcherised face stimuli.

Sunday PM

36.315 **Increased Contrast using Computer Manipulations: An Exploitation of an Innate Attractiveness Preference in Female Faces?**

Amanda C. Killian[1](amandakillian@csu.fullerton.edu), James L. Guidangen[1], Jessie J. Peissig[1]; [1]Psychology Department, California State University Fullerton

Attractiveness is a part of our daily lives. We attribute positive and negative qualities to those who we perceive as either attractive or unattractive (Symons, 1979). In most cultures women apply makeup to enhance their facial attractiveness; in particular, makeup is commonly applied to the eye and mouth regions of the face. In recent studies, increased luminance contrast in these regions has been found to increase attractiveness for females but not males (Russell, 2009). In this study we examined different regions of increasing luminance contrast in female faces using computer manipulations. The data showed that not all increased contrast within the eye region is attractive. When the sclera and iris are included, raters do not find these faces to be significantly more attractive than the same face with no increased contrast. This could be attributed to the contrast as an indicator of good health, in addition to its relationship to attractiveness.

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36.316 **Individuation Experience Predicts Other-Race Effects in Holistic Processing**

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Same-race (SR) faces are recognized better than other-race (OR) faces, and this other-race effect (ORE) is correlated with experience. SR faces are also processed less holistically than OR faces, suggesting one possible mechanism for poorer performance on OR faces. Studies of object expertise have shown that individuating experiences are necessary for holistic processing to develop; yet thus far no studies have investigated the role of quality of experience and the ORE for holistic processing. In the present study, we found a strong negative correlation between a self-report of individuating experience and the ORE in holistic processing in both Caucasian and Black participants, indicating that the more individuating experience a person has, the less ORE in holistic processing. This confirms the critical role of individuating experience in development of holistic processing for faces and suggests that quality of experience is a key determinant of the manner in which OR faces are processed.

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36.317 **Resolving the Holistic Processing / Face Recognition Debate**

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Although holistic processing is thought to underlie normal face recognition ability, widely discrepant reports have emerged about this link in an individual differences context (Konar et al., 2010; Richler et al., 2011). Progress in this domain may have been impeded by the widespread use of subtraction scores, which typically lack validity due to their contamination with control condition variance. A more valid alternative is to regress, rather than subtract, control conditions from primary conditions (Peter et al., 1993). Using 43 participants, we measured the relationships amongst the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) and two holistic processing measures, the composite task (CT; Young et al., 1986) and the part-whole task (PW; Tanaka et al., 1993). For the CT and the PW, we contrasted the results for regressing versus subtracting out the control conditions (parts for the PW; misalignment effect for the CT) from the primary conditions (wholes for the PW; alignment effect for the CT). Both regression based measures of holistic processing correlated with the CFMT and with each other. Interestingly, the "complete design" subtraction measure of the CT used by Richler and colleagues (2011) correlated almost as highly with the CFMT as did our regression based measure, suggesting that its contamination with control task variance has a relatively modest end result. However, the subtraction based PW measure correlated neither with the CFMT nor with the CT, suggesting that the PW takes a major hit in validity when computed with a subtraction based approach. In sum, using a regression based approach, we confirm the hypothesized link between holistic processing and face recognition and demonstrate a theoretically crucial link amongst holistic processing measures. The present results illustrate the utility of a regression based approach for associating and dissociating aspects of human cognition via individual differences.

36.318 **Holistic face processing induces perceptual shifts in face perception**

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Numerous behavioral studies have demonstrated that face recognition depends on holistic processing, based especially on the famous composite face effect. The decline in hit rate when composite halves are aligned compared to when they are misaligned is taken to reflect interference from the whole-face configuration. However, whether this interference is due to a perceptual bias or reduced discriminative efficiency is still a matter of debate. To clarify the nature of this effect, we devised a new composite paradigm using ambiguous stimuli. We generated three series of morphed faces derived from merging pairs of celebrities. Ambiguous morphed top-halves were coupled with unmorphed bottom-halves, the two halves being aligned or misaligned. The task was to say which celebrity the ambiguous top-half most resembled. We plotted the frequency of response and response time as a function of the morphing level of the top-half and the identity of the unmorphed bottom-half. We examined whether, compared to the misaligned condition, the data in the aligned condition showed a decrease in slope of the psychophysical function, which would indicate reduced discriminative efficiency, or a change in intercept alone, which would indicate a perceptual bias. 30 healthy participants performed this task. Our results showed that the bottom-half altered responses to the top-half when faces were aligned but not when they were misaligned. More crucially, the change was due to a shift in the position of the psychophysical function ($p<0.001$) without a significant change in the slope of these functions. These results demonstrate that the composite illusion originates in a perceptual bias introduced from one face-half that affects the decision about the identity of the other face-half when they are aligned, and is not

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from decreased discriminative efficiency of judgments about that other face-half, due to reduced attention, interference, or other possible mechanisms that can degrade perception.

36.319 Clinical bias in holistic face perception

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Latest research repeatedly showed that face processing significantly differs from processing of other objects. Instead of being processed on a purely featural basis, processing of faces seems to rely considerably on configural properties (e.g., Farah, Wilson, Drain, & Tanaka (1998). What is "special" about face perception? Psychological Review, 105, 482-498.). Also, it was recently found that especially vertical relationships of facial features are vulnerable to inversion (Goffaux, 2007), again suggesting that configural information in faces is crucial in face perception. Accumulating evidence suggests that clinical populations exhibit strong impairments in their face perception capacity, which may be linked directly to the different processing regimes of featural and configural facial information. In this study we aimed to show that social phobics (n=15) and depressive patients (n=25) differ from a normal control group (n=30) by using experimental designs with locally and globally manipulated (expt. 1) as well as contextually modulated (expt. 2) faces. Experiment 1 was designed as a face identity discrimination task to measure perceived differences between two faces that have been manipulated in one of three possible variables (exchanged eyes, exchanged eyes and mouth and vertical eye movement in second picture). The discrimination task in experiment 2 focused on evaluation of part-based or featural replacements within faces in the upper or lower part of a face with the corresponding face part as a present distractor. Congruent and incongruent samples were presented in both upper and lower part of each face. Results indicate that clinical groups, particularly depressive patients, generally perform on a weaker level than healthy controls. Also they are less sensitive for global face manipulations and show greater performance bias in incongruent face context. These results suggest a global cognitive impairment through psychological and mental illnesses and primarily for depressive patients a differential impairment of holistic face processing.

36.320 Facial Motion Influences Featural, But Not Holistic, Face Processing

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We report three experiments in which we investigated the effect of facial motion on face processing. Specifically, we used the face composite effect to examine whether and how rigid facial motion influences primarily featural or holistic processing of faces. In Experiments 1 and 2, after familiarization with dynamic displays in which a model's face turned from one side to another, participants judged whether the top half of a composite face belonged to the same model. By comparing performance to various static control conditions in Experiments 1 and 2, which differed from each other in terms of stimuli display inter-stimuli interval (ISI), we found that the size of the face composite effect in the dynamic condition was much smaller than that in the static conditions. In other words, the dynamic face display appeared to promote mainly face featural processing that allowed participants to extract more readily the upper portion of the composite face. Further, in order to investigate whether this influence is specific to rigid facial motion or a general one that existed in other facial motions, we changed the rigid facial motion to non-rigid one (i.e., chewing animation) in Experiment 3. The results supported that the facial motion could generally influence the facial featural processing by showing a similar smaller composite effect led by dynamic faces, as compared to static ones. The findings from the present experiments provide the strongest evidence to date to suggest that the facial motion mainly influences facial featural, but not holistic, processing.

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36.321 A new fat face illusion: Psychophysical evidence

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We report a series of experiments to investigate a novel fat face illusion: when two identical images of the same face are aligned vertically, the face at the bottom appears "fatter" than the top one. In Experiment 1, we showed this illusion to emerge only when the faces were presented upright, but not when inverted. In Experiment 2, a JND procedure revealed the size of the fat face illusion to be 4%. That is, the bottom face appeared to be 4% bigger than its actual size. In Experiment 3, clocks were shown in the same vertically aligned fashion as the faces but we failed to observe a similar illusion, suggesting that the fat illusion does not generalize to every category of canonically upright objects with similar geometric shape as a face. In Experiment 4, participants still reported a fat face illusion when observing the two identical vertically aligned upright faces with inverted eyes and mouth. However, a reverse fat illusion (the top face being fatter) emerged when the face was inverted but the eyes and mouth remained upright. These findings taken together demonstrated that the fat face illusion is influenced by both configural and featural information in a face, suggesting that this effect could not simply be explained as a special case of the Jastrow illusion (1891) because the latter is not sensitive to geometric shape orientation, or internal elements, or the relationship between internal elements and the geometric shape that encompasses them. Potential mechanisms of the fat face illusion and the implications for understanding face processing are discussed.

Motion: Biological II

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

36.322 Temporal Characteristics of Neural Processing During Action Perception: The Role of Biological Form and Biological Motion

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Successfully perceiving and understanding others' body movements supports a variety of perceptual and cognitive processes such as recognizing people, understanding events, detecting communicative intent, inferring intentions, feeling compassion and empathy toward others (Blake & Shiffrar, 2007). Despite intense interest from various sub-fields of cognitive neuroscience, there are many unknowns regarding how our brains support these functions. Here, we investigated the temporal characteristics of neural processing during action perception using electroencephalography (EEG). We used a novel stimulus set of well-matched human and humanoid robot actions to study the role of visual form and motion kinematics of the observed agent during action processing. Event-related brain potentials (ERP) were recorded while participants viewed 2s videos of three agents (Human, Android, Robot) performing recognizable actions: Human had biological form and motion, Android had biological form and non-biological motion, Robot had non-biological form and non-biological motion. Android and Robot were the same moving machine disguised via two different appearances, and thus featured identical kinematics. We found distinct neural signatures for processing of biological form and motion, as well as for congruence of form and motion. Form-sensitive modulation was characterized by 1) a negativity between 210-400 ms over centro-parietal, central, and fronto-central regions bilaterally, 2) a positivity between 270-370 ms over left parietal areas, both more pronounced for Robot compared with Human and Android. There was some evidence for biological motion-sensitivity between 130-230 ms, over left parieto-occipital regions, Human being more pronounced than Android. There was also evidence for a neural signature for processing of form-motion congruence in frontal regions between 150-250 ms, where the Android condition differed from Robot and Human. These results highlight differential spatiotemporal cortical patterns in action perception that depend on the viewed agent's form and motion kinematics.

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36.323 Increment threshold functions for radial frequency motion trajectories exhibit a dipper function above threshold

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Radial frequency (RF) trajectories are a new class of stimuli that have been developed to study the visual perception of periodic motion (Or, Thabet, Wilkinson, and Wilson, 2011). These stimuli are described by a moving dot that traverses a circular path through space with periodic radial deformations whose frequency, amplitude, and phase can be independently specified. Here, we show how the discrimination of RF amplitude varies across different reference amplitudes in a 2 alternative forced choice task. Using an RF3 trajectory (a pattern with three cycles of deformation along its trajectory), increment thresholds for seven observers were measured at four different reference amplitudes: Detection (discriminating a circular motion from RF3), 1X (discriminating a pair of RF3 patterns, with the amplitude of one member of this pair set to (1X) threshold obtained from the detection condition), 2.5X, and 5X. Data show that thresholds for detecting changes in amplitude show an approximately two-fold decrease at 1X and 2.5X, relative to detection threshold, and then recover to detection threshold levels at 5X. Mean thresholds (± standard errors) for detection, 1X, 2.5X, and 5X (in minutes of arc): 2.30 ± 0.31, 1.21 ± 0.18, 1.06 ± 0.12, 2.31 ± 0.42, respectively. A repeated measures ANOVA showed a main effect of base increment: $F(1,6) = 95.80$, $p<0.0001$); paired sample t-tests showed a significant difference between detection and 1X, $T(6) = 3.59$ ($p<0.05$); detection and 2.5X, $T(6) = 4.28$ ($p<0.01$); and no difference between detection and 5X, $T(6) = -0.03$ ($p = 0.98$). Observers were also tested using an RF5 trajectory, and the same pattern was found. As a control, this effect was measured using different angular speeds of the RF trajectory. We conclude that the discrimination of RF trajectories along different base amplitudes points to a sigmoidal neural response function for deviations from circular trajectories.

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36.324 Recognizing activities and poses: lessons from computer vision

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There has been extensive research aimed at understanding how we perceive human bodies and human movements. A number of methodologies have been employed for this research: psychophysics, neuroimaging, and computational modeling. However, most studies, especially psychophysical and computational studies, have only considered the case of point light animations (Johansson, 1973). Meanwhile, in the field of computer vision, there has been a dedicated effort to identify human figures in real world images and videos. Computer vision models that operate on real world visual inputs can be informative for perceptual investigations. We were inspired by the observation that successful computer vision models of action and pose recognition perform qualitatively different computations - one driven by holistic features, and the other driven by deformable templates based on the human form. We wanted to understand if this difference in computational strategy for recognizing actions vs. poses reflected differences in human perceptual processing as well. We collected photographs of human figures performing one of six common activities (e.g., bending, kicking, etc.) and for each activity, included a variety of poses, backgrounds, lighting, body types and clothing. We annotated the pose in each photograph (Bourdev & Malik, 2009) to create 3D stick figure representations. Observers were then asked to recognize either the activity or the pose depicted in the photographs by selecting one of six options (e.g., list of activities, or set of stick figures). We found that action recognition was faster and more accurate than pose discrimination. Standard actions like walking or sitting can be predicted even when the human figure is occluded, which suggests the importance of real world cues like support surfaces and scene context for recognizing actions. Taken together, our findings support the use of divergent strategies in computer vision for recognizing actions (fast, context-driven) and poses (slower, template-based) in real world images.

Acknowledgement: NSF

36.325 The Role of Motion and Form in the Sex Aftereffect in Biological Motion.

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Previous research has shown that adapting to point light walkers (PLWs) can create a sex aftereffect; for example, adapting to a male PLW results in a bias to perceive subsequently viewed PLWs as female. We sought to determine what information within the PLWs creates this sex aftereffect. In a series of four experiments we measured the sex aftereffect on PLWs with the following adapting stimuli: 1) a PLW, 2) a stationary full body image, 3) a PLW consisting of just the hip and shoulder movements, 4) a static PLW, 5) a PLW consisting of hip, shoulder, and foot movements, and 6) static lines representing the arms and legs. Participants viewed the adapting stimulus, either male, neutral or female, for 8 to 10 seconds on each trial immediately followed by the PLW serving as the test stimulus for one or two seconds. The test PLW varied from trial to trial and ranged from male through neutral to female. After the test PLW disappeared, participants indicated whether it appeared to be male or female by pressing a key on a response box. Data from each experiment were analyzed with a three way repeated measures ANOVA (adaptation type, adaptation sex, test sex). In all experiments we replicated the basic sex aftereffect when using a moving PLW. However, the only other adapting stimulus to create a sex aftereffect was adaptation to a static PLW (none of the other adapting stimuli resulted in a significant effect of adaptation sex). The results lead us to three conclusions: 1) motion information is not necessary to create a sex aftereffect in PLWs, 2) information about shape that can be represented with static dots is critical in creating the sex aftereffect in PLWs, 3) a general sex perception mechanism is not responsible for the sex aftereffect in PLWs.

36.326 Discriminating emotions from point-light walkers in persons with Schizophrenia

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The visual system is well adapted to recognize human motion from point lights attached to the major joints of an actor. Moreover, individuals are able to recognize emotions based on the visual information in such dynamic point-light displays. This ability is important because humans utilize both biological motion and affect recognition for understanding the intentions of people in the environment. It is not clear, however, whether atypical observers, including people with schizophrenia, also process visual information about emotion in point-light walkers in the same way. There is evidence that people with schizophrenia are impaired in recognizing emotional expressions. Furthermore, people with schizophrenia are known to have deficits in social perception. For these reasons, we investigated whether the ability to recognize emotions from point-light displays is altered in people with schizophrenia. In the current study, groups of healthy community-based controls (N=33) and people with schizophrenia (N=33) were asked to discriminate the emotions of four types of affective point-light walkers: upright, inverted, scrambled (which contained only local form information), and random-position (which contained only global form information). The point-light walkers were presented in three emotional conditions: happy, sad, and angry. Both healthy controls and people with schizophrenia were able to discriminate emotions from point-light walkers, where performance was best for upright walkers, worst with scrambled walkers, and intermediate with random-position and inverted walkers. Overall, performance was worse for people with schizophrenia compared to healthy observers. These results suggest that both healthy controls and people with schizophrenia are able to recognize emotions from point-light walkers on the basis of local motion or global form information alone. However, performance is best when both form and motion information are presented simultaneously, and, although they do perform above chance, people with schizophrenia are relatively impaired in all conditions.

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36.327 Heritability of local but not global biological motion processing in the human brain

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Biological motion enjoys privileged processing in the human visual system. Whether it is endowed by nature or shaped through postnatal experience remains controversial. Here we provide the first behavioral genetic evidence upon this issue using a classic twin design. We specifically aimed to examine the heritability of two fundamental components (i.e., the local motion and the global configuration) in support of biological motion perception. The local motion component was extracted by spatially scrambling intact point-light walkers, whereas the global component was obtained through embedding the point-light walkers in dynamic noises composed of pure local biological motion cues. Results revealed a reliable genetic contribution to individual variations in local but not global biological motion perception with the latter largely explained by environmental factors. Taken together, our findings point to an innate mechanism disposed to the processing of local biological motion cues. Men may learn to interpret the global configurations of biological motion, but their sensitivities to its inherent kinetics are mainly hardwired in the brain.

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36.328 Perception of emotion from interactive body movement: influence of emotion congruency

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INTRODUCTION: Most studies on the perception of emotional body language have focused on emotion expressed by individuals. However, a large part of the emotions relevant in everyday life occur in interactive situations, involving multiple individuals. We started to study such movements systematically exploiting motion-capture and methods from computer graphics that, opposed to video recordings of real scenes, provide an exact control of the stimulus properties. We investigated how the congruency of the emotions expressed by two interacting partners influences the perceived emotional expressiveness. METHODS: Visual stimuli showed computer animations based on a motion-captured scene, where one actor (A) approached another actor (B) from behind, and tapped him on his shoulder in different emotions following mood induction. We created stimuli from different actors (A) expressing anger or no emotion. The reaction of the second actor (B) was manipulated by replacing the original reaction by the corresponding action in different moods. Additionally, we created stimuli without any reaction of (B), showing (A) alone. Participants rated the angriness of (A) on a Likert-Scale ranging from 1 "not angry" to 5 "extraordinarily angry". They were explicitly asked to ignore the reaction of (B) in the scene. RESULTS: The emotion of the target character (A) was reliably recognized. In addition, we found a profound influence of the emotion expressed by the second character (B) in the scene on the participants' ratings (ANOVA 'Reaction' $F(3,42)=14.98$, $p<0.001$, 'Emotion' $F(1,14)=89.16$, $p<0.001$). The strongest angriness rating for (A) was observed if (B) reacted angrily as well, irrespective whether (A) was neutral or angry. CONCLUSIONS: These results are compatible with an interpretation in terms of social context that has a strong influence on the perception of affect. Future experiments might reveal whether this influence is limited to negative emotions or does also apply to positive affects as happiness.

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36.329 A model of three-dimensional biological motion perception from two-dimensional views

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Most studies of biological motion perception have used walkers seen in profile from the side. However, recent psychophysical and electrophysiological investigations have found that recognition ability is different for different views (frontal, half-profile or profile), and that body posture sensitive cells in the ventral visual system are tuned to the facing-in-depth of the body. We present a neural model of three-dimensional biological motion perception from two-dimensional views, based on earlier modeling work with profile views. The model consists of posture-sensitive cells that each represent a 2D view of particular body posture. Template matching between the stimulus and the posture cells induces a temporal variation of activity in the body posture representation tuned for a particular view. Temporal filters then create a representation of body motion. The model is tested in comparison to psychophysical and electrophysiological data. It reproduces the dependence of recognition ability on view orientation, and certain ambiguities both in perception and in the neuronal tuning functions for body views in primate STS. Because the model uses primarily body form information, along with its temporal evolution, it is helpful in explaining how much of the specificities of 3D biological motion perception rely on the geometrical properties of the stimulus.

36.330 Position and size invariance in the mechanisms of biological motion perception

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Biological motion, the perception of a moving human figure from point-light stimuli, may be derived from the analysis of sequences of body posture by body selective neurons in the ventral visual system. These neurons are likely to show position and size invariance to their preferred stimuli. We investigated biological motion perception from sequences of point-light images that changed in position or size from frame to frame. In the size change condition, stimulus size changed randomly between 1.59 and 7.31 deg from frame to frame. In the position change condition, stimulus size was 1.59 deg, and stimulus position was random on a circle of radius 3.18 deg. In one experiment, 150 naive subjects verbally described their spontaneous percept of one such stimulus. 60,5 % of the subjects correctly recognized biological motion despite the variability of the size and position of the individual frames. In a control condition, in which the same posture was used in all frames only 16 % reported seeing a human figure. In a second experiment, 11 subjects discriminated facing and moving direction of the walkers in a psychophysical experiment. Correct recognition rates were 91 % for the facing discrimination and 69 % for the walking direction discrimination. We conclude that biological motion can be perceived even from stimuli that vary unnaturally in size and position, consistent with an involvement of size and position invariant form recognition mechanisms in the ventral visual system.

36.331 Biological motion as a cue for spatial attention: Walking

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Introduction: Movements of living entities in our environment are an important source of information. Here we explored walking movements as a cue for attention. A recent study reported a point-light walker (PLW) could induce reflexive attentional orienting in the direction it is facing, even when it is task irrelevant (Shi, et al., 2010). Given direction information from PLWs can be extracted without motion (Lange & Lappe, 2006) or from local motion alone (Troje & Westhoff, 2006), we wondered whether the attentional orienting effect was driven by form- or by motion-based processes. Methods: Subjects viewed PLWs that faced left or right that could also walk forward or backward (i.e., PL moonwalkers). A gabor patch was then presented either on the left or the right side of the screen. In Experiment 1, all PLWs were presented centrally and were task irrelevant. In Experiment 2, we presented occasional scrambled "catch" trials requiring subjects to attend the PLWs (even though they still did not cue target locations). We also presented the PLW cues both centrally and peripherally. Results: Experiment 1 failed to replicate Shi et al (2010): There was no evidence of attentional orienting in our data, neither for facing, nor for walking direction. In Experiment 2, where subjects had to attend the PLWs for an unrelated task, subjects were significantly more accurate in responding to targets congruent with the motion direction of the PLW. The effects were found only for central presentation of the PLWs. Conclusions: Reflexive attentional orienting effects induced by a PLW appear to be fickle. When subjects did not attend the PLW, there was no attentional effect. When subjects attended the PLW, we found a significant effect of motion direction, and not facing direction, and only when the PLW was presented centrally.

Acknowledgement: Supported by Hellman Foundation Research Fellowship and California Institute for Telecommunications and Information Technology (Calit2). We thank Luke Miller, Edward Nguyen and Maria Florendo..

Sunday PM

36.332 **Biological motion as a cue for spatial attention: Pointing**

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Introduction: Movements of living entities in our environment are an important source of information. Specifically, spatial attention can be directed by others' eye gaze and pointing. Here we tested whether biological motion dynamics influences the use of pointing movements as a cue for attention. Methods: Subjects viewed videos of pointing movements by an adult human and an android made to resemble the human (Repliee Q2). The two agents had very similar appearance but whereas the former moved with natural biological motion dynamics, the latter was a robot that moved mechanically. After each video, a gabor patch was presented either on the same side of the screen as the pointing movement (congruent) or on the opposite side (incongruent). Participants were asked to respond by pressing one of two buttons to indicate the location of the gabor. Results: There was an interaction between congruence and the viewed agent. Non-biological motion (android) was in fact a stronger cue for attention compared to biological motion (human). We hypothesize the android, which features a human appearance but mechanical motion, leads to stronger attentional effects due to its novelty and/or the uncanny valley phenomenon (where viewers have a negative response towards artificial agents that are too close to human). Conclusions: For pointing movements, biological motion dynamics does not appear to increase spatial attention to the pointed location. Instead, the non-biological pointing movement of the android was a more effective attentional cue. Follow-up studies with less humanlike robots are needed to determine whether this effect interacts with biological appearance.

Acknowledgement: Supported by California Institute for Telecommunications and Information Technology (Calit2), Kavli Institute for Brain and Mind (KIBM). We thank Hiroshi Ishiguro and Burcu Urgen.

Attention: Neural mechanisms and models II

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

36.401 **Opposite neural responses for visual stimuli above and below perceptual threshold**

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Visual events come at an enormous range of intensities - from the faint light in the dark to the blinding light of the midday sun. How does the visual system respond to stimuli of such different intensities? A number of experiments have reported weaker, but similar brain responses for stimuli of strong intensity that were made invisible by masking. However, it is currently unknown whether the visual system responds in a similar fashion to stimuli that are invisible due to their low contrast. Somatosensory stimuli of low intensity cause a deactivation of somatosensory cortex rather than just a weak activation as has been demonstrated using fMRI. These so called subliminal visual stimuli therefore elicit a response that is opposite from conscious, supraliminal stimuli. The deactivation in response to subliminal stimuli has been interpreted as a focal inhibition mechanism that protects the cortex against spurious activation due to noise. In visual cortical areas, functional activation is related to reduced alpha-band (8-14 Hz) power while deactivation is related to elevated alpha power. In the present study, we tested the hypothesis that – as in the somatosensory system – low-intensity stimuli result in neuronal inhibition as indicated by alpha power increase while high-contrast stimuli result in alpha power decrease. We investigated EEG responses to subliminal and supraliminal visual stimuli after estimating each participant's detection threshold. Stimuli consisted of peripherally presented small circular patches displayed on a background consisting of a random white noise pattern. We demonstrate that low- and high-intensity stimuli indeed induce opposite effects in the alpha-band: while supraliminal stimuli induce a decrease in alpha-band power, subliminal visual stimuli induce an increase in alpha-band power. This indicates that the visual system uses an inhibitory mechanism to counter spurious activation that is unlikely to be caused by real events in the world.

36.402 **Sluggish Attentional Shifting Seems Genetically Determined in Developmental Dyslexia: Evidence from the Nicotinergic Receptor Alpha 4 Subunit Gene**

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Developmental dyslexia (DD) or reading acquisition disorder, is a heritable multi-factorial condition. In addition to the typical auditory and phonological deficits that characterize the DD, there is evidence for a sluggish attentional shifting. Since attentional shifting is mainly mediated by the brain nicotinergic system, it is conceivable that the polygenic basis of DD may encompass nicotinergic receptor genes. Here, we addressed whether nicotinergic receptor alpha 4 subunit gene (CHRNA4) variation (i.e., rs3827020 TC/CC vs. TT genotype) influences transient spatial attention in 100 children with DD. The time-course of transient spatial attention was measured by using a spatial cuing paradigm: A peripheral and uninformative cue preceded the onset of a lateralized target stimulus in the same (valid cue) or different (invalid) location. Two different cue-target intervals were employed as well. We found a specific association between transient visual attention and CHRNA4. In particular, TC/CC dyslexics showed a slower time-course of transient spatial attention compared with TT dyslexics. Thus, we provide an evidence that specific genes can be associated with specific phenotypes of the multifaceted neurocognitive impairment of DD.

36.403 **Attentional shifts underlie hemispheric asymmetries in topographic parietal cortex**

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The intraparietal sulcus (IPS) has been implicated in a broad range of perceptual, cognitive and motor functions. Within IPS, at least 7 visuotopically-organized areas have been described and characterized. However, it is unclear how attention affects the spatial profile of responses in these areas. We therefore used fMRI and population receptive field (pRF) mapping to investigate the relationship between spatial attention and topographic organization in parietal cortex. Ten subjects (4 left-handed) performed 6 runs each of an attend-to-fixation and an attend-to-stimulus condition. In the attend-to-fixation condition, subjects detected a luminance change at fixation while a bar containing a field of coherently moving dots traversed the visual field. In the attend-to-stimulus condition, subjects covertly attended the bar and detected a change in direction of the coherent motion within the bar. Eight stimulus blocks and 4 fixation blocks per run were used to determine the center and size of the pRF for each voxel, with the bar traversing the visual field in a different direction for each stimulus block. To estimate the degree of lateralization for each pRF, we computed a lateralization index based on the pRF's preferred location and size in each condition. Visuotopic parietal cortex demonstrated a hemisphere-dependent decrease in lateralization in the attend-to-stimulus condition relative to the attend-to-fixation condition. The decrease in lateralization was a result of increased pRF size in the hemisphere ipsilateral to the subjects' dominant hand (right hemisphere for right-handed subjects and in the left hemisphere for left-handed subjects). While attending to the stimulus also increased pRF size in the hemisphere contralateral to the subjects' dominant hand, representations in the contralateral hemifield shifted towards the periphery, resulting in a preservation of lateralization. These results demonstrate that spatial attention shifts visual field representations in visuotopic parietal cortex in a hemisphere- and handedness-dependent manner.

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36.404 **Top-down attentional selection as a marker of learning: An ERP study**

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Attentional target selection is based on top-down search templates when target-defining features are specified in advance. However, little is known about how observers learn what to look for. The present ERP study investigated how known or newly learned perceptual categories affect the emergence and speed of spatially selective processing in perception (N2pc component) and working memory (SPCN component). Adult participants had to select targets among distractors in a familiar (digits and letters) and a novel context (Chinese characters – numbers and non-numbers). On each trial, targets were specified by a preceding prime array. Identity prime arrays (two identical items) instructed participants to simply select the physically identical target item (if present) in the next search array. Category primes (two different items belonging to the same category) instructed participants to select a category-matching target in the next search array. As expected, all targets triggered N2pc and SPCN components in the familiar context. N2pc onset was earliest when targets were specified by identity primes, demonstrating fastest target selection when targets and search templates match physically. In the novel context, targets specified by identity primes or by physically matching category primes also triggered N2pc and SPCN components, as participants could again base target selection on physical identity on these trials. However, when targets were specified by non-matching category primes, and this strategy was not available, target selection required the prior learning of the relevant category. On these trials, no lateralized ERP components were triggered during the first experimental session. Critically, a reliable SPCN was triggered by a category-primed target during the second session, demonstrating that this component is a marker of successful category learning. Our study provides new insights into the real-time dynamics of top-down attentional selection guided by physically or categorically defined attentional templates, and into the acquisition of new perceptual categories.

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36.405 **The effects of selective and divided attention on sensory integration**

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While top-down attention and multisensory integration have been investigated extensively as independent concepts, little is known about how these processes interact, and how these interactions may be affected by attentional load. We investigated this topic using two paradigms: in one experiment, participants localized auditory, visual, and audiovisual stimuli in single-response conditions requiring attention to one sensory modality, and dual-response conditions requiring attention to two modalities. In a second experiment, participants again performed the spatial localization task and attended either to one sensory modality or both sensory modalities, but a secondary detection task was included in each condition to equate attentional load across conditions. To analyze data from both experiments, we used a Bayesian causal inference model (Wozny et al., 2010) to computationally characterize the effects of selective and divided attention by comparing priors and likelihoods across attention conditions. Results from Experiment 1 indicate that selective attention to one modality results in more precise sensory representations than divided attention (to both modalities) in both the visual and auditory domains (demonstrated by reduced variance in the likelihood distributions), and leads to a stronger tendency to integrate stimuli across modalities (as evidenced by an increase in the prior bias for perception of a common cause). Results from the second experiment did not show any significant differences between conditions in which attention is divided within or across modalities. If each modality had its own separate attentional resources, then attending to two tasks across modalities should have been less disruptive (i.e. smaller likelihood variance) than attending to two tasks within the same modality. Thus, the absence of differences between crossmodal and within-modality divided attention suggests that the auditory and visual modalities do not have independent processing resources, at least in a spatial localization task.

36.406 **Divided attention limits perception of object shapes but not simple features**

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Can one perceive the shapes of multiple objects in parallel? Or must one “read out” the shapes one-by-one, as if reading words? Our recent experiments support the latter notion. We tested two extreme benchmark models of object shape perception under divided attention: an unlimited-capacity and a fixed-capacity model. In an unlimited-capacity model, shapes are analyzed independently and in parallel. In a fixed-capacity model, shapes are processed at a fixed rate (e.g., serial processing). METHODS. To measure the capacity limits, we used a variant of the simultaneous-sequential paradigm (Scharff, Palmer, & Moore, 2011a, 2011b). The stimuli were photographs of novel physical objects: foam blocks, lego constructions, and crumply papers. The use of novel objects minimized the role of semantic categorization in the task. Observers searched for a particular exemplar among similar objects from the same set, insuring that non-shape stimulus properties (such as color and texture) could not be used to complete the task. Variable viewpoints were used to preclude image-matching strategies. RESULTS. The results reject an unlimited-capacity model for shape perception, and are consistent with the predictions of a fixed-capacity model. A similar fixed-capacity limit has been previously observed in tasks that required reading words and making semantic categorizations of images (Scharff, Palmer, & Moore, 2011a; 2011b). Further experiments show that capacity limits are independent of task difficulty and are not mediated by mental rotation of objects. DISCUSSION. While this study with 3D objects yielded limited capacity results, comparable studies on simple shapes and surface completion yielded results consistent with unlimited capacity. Together, the results indicate a narrow attentional bottleneck in some aspect of processing between elementary surface perception and object shape perception.

36.407 **Multiple roles of attention: physiological evidence from a change blindness task**

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When exploring a visual scene, attention can be allocated to different regions according to the attentional priority of the objects in the scene. These priorities are represented in the lateral intraparietal area (LIP). It’s also well established that V4 responses are modulated by attention. We asked how neurons in these areas respond when attention is focused or spread while animals perform a change blindness task. In this task, an array of 1, 2, 4 or 8 oriented bars was flashed for 500 ms at equal eccentricities. After a gap of 50-300 ms, the bars reappeared for 1000 ms. In some trials, one of the bars had rotated 90 deg. The animal had to saccade to this bar to be rewarded. In the remaining trials, no bar was rotated and the animal was rewarded for maintaining fixation. Performance decreased as the number of bars increased, suggesting that attention was spread and that the attentional resources at each location decreased. Accordingly, LIP responses showed a set-size effect, with decreasing activity as the number of bars increased. However, V4 activity did not differ as a function of set size, suggesting that the decrease in behavioral performance is the result of down-stream processing rather than an attentional effect in visual cortex. In another block of trials, one of the locations was loaded by a significantly larger reward: a “hot spot”. Attention was biased toward the hot spot in both subjects, resulting in an increase in both performance and neuronal responses in both V4 and LIP. This result suggests that traditional attentional modulation can still be elucidated in both LIP and V4 while the animals are performing this task. We conclude that covert attention acts to affect down-stream processes in addition to its known role in modulating responses in early visual areas.

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36.408 **Covert attention to bright and dark surfaces drives pupillary responses**

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Changes in pupil size are most often attributed to changes in light levels – an increase in ambient light results in constriction and a decrease results in dilation. However, a variety of perceptual, cognitive and motivational factors have been shown to influence pupil size suggesting complex feedback circuits from higher-order brain structures. This circuitry raises the possibility that the behavioral relevance of a particular light level in an image could affect pupil size. Specifically, we addressed whether – while keeping eye position fixed – attending to a brighter or darker part of an image results in pupillary constriction and dilation, respectively. Test displays consisted of one bright and one dark disk presented on the left and right side of a uniform gray background. A trial consisted of cueing to which side (left or right) to shift attention, followed by a brief interval, and then the presentation of the two disks. Attention direction and spatial position

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of the bright and dark disks were counterbalanced across trials. To ensure task engagement, subjects were asked to count, and respond with a button press at the end of the trial, the number of brief changes in chromaticity of a small colored dot located in the center of the attended disk while ignoring color changes in the dot located in the unattended disk. We found that attending to the bright and dark disks produced reliable pupil constrictions and dilations, respectively. Since, under natural viewing conditions a shift of attention is usually followed by an eye movement in the same direction, our data suggest that the visual system – even at the level of the pupil – anticipates and adjusts to future light level conditions.

36.409 Space-based and Feature-based Attention in a Realistic Layered-microcircuit Model of Visual Cortex

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Attention towards space and feature modulates various levels of neural responses and perceptions. However, spatial and feature-based attention differently affect visual processing and perception via their gain and tuning properties (McAdams and Maunsell, 1999; Martinez-Trujillo and Treue, 2004; Ling, Liu and Carrasco, 2009). We examined computationally a mechanism of the type-specific attention modulation through a layered visual cortical microcircuit model based on current knowledge of cortical neurobiology. The proposed microcircuit model consists of eight orientation columnar circuits in V1, each sharing their receptive fields. A column is based on about 20,000 integrate-and-fire neurons and represents layers 2/3, 4, 5 and 6 (Potjans and Diesmann, 2011). These columns primarily interact via lateral inhibitions from layer 2/3 excitatory neurons in one column to layer 2/3 inhibitory in others (Wagatsuma, Potjans, Diesmann and Fukai, 2011). We introduced additional inter-columnar connections between excitatory neurons residing in columns of similar selectivity. Eight columns receive different preferred bottom-up visual stimuli at layers 4 and 6 as well as selective top-down feature-based attention at layers 2/3 and 5. In contrast, top-down spatial attention is homogeneously projected to all columns without the dependence on their selectivity. Our model quantitatively reproduced the type-specific attention modulations reported from physiological studies: spatial attention indicated a multiplicative scaling of the responses of all orientations, whereas feature-based attention both increased the gain and sharpened the tuning curve. Furthermore, the simulations of the model with various levels of external noise showed good agreement with psychophysical observations: spatial attention increased discriminability only when the low external noise, whereas feature-based attention boosted the performance at both low and high level of noise. These simulation results suggested that the allocation of top-down signals and the inter-columnar synaptic connection within the subpopulation of the visual cortex underlie the type-dependent attention modulations of neuronal responses and visual perception.

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36.410 Which side are you on? An exploration of hemispheric specialization and visual attention.

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While the two hemispheres of the brain work together, research examining many sensory realms has shown that they are also specialized for different tasks. Generally, the dichotomy of the left and right hemispheres has focused on linguistic abilities; however, Kosslyn (1987) suggests a visual information-processing dichotomy in that the left hemisphere is superior at processing categorical visual information and the right hemisphere is specialized for processing spatial visual information. The purpose of the current study was to examine a possible right and left hemisphere difference in change detection performance. Based on Kosslyn's (1987) findings, it was hypothesized that there would be superior performance for detecting identity changes (more categorical) in the left hemisphere and superior performance for detecting configuration changes (more spatial) in the right hemisphere. Observers view an array of three shapes presented to either the left or right visual field. The initial array was presented for 150ms followed by an 80ms blank screen that was then followed by either an array of three new shapes in the same positions (identity change) or an array of the same shapes in three different positions (configuration change; final array present for 150ms). Observers also viewed no change trials and their task was to determine, as quickly as possible, whether a change had occurred. There were no differences in change detection accuracy for hemisphere and type of change. For reaction time performance, there was a marginally significant difference for configuration changes, but no effect for identity changes. Reaction time for configuration changes was faster when presented to the right hemisphere compared to the left hemisphere. This may suggest that a hemispheric dichotomy exists for visual attention related to change detection and future research should continue this investigation.

Attention: Exogenous and endogenous

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

36.412 Opposite effects of external and internal conflict on subsequent behavior

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Previous studies have demonstrated that interference is reduced following external conflict that is defined by stimulus properties. This reduced interference represents a decreased level of internal conflict during the observer's decision–making process. However, it is unknown whether the magnitude of internal conflict influences subsequent behavior in the same way that external conflict does. To concurrently examine the role of both external and internal conflict on subsequent behavior, we used a visually-guided reaching task in which reach trajectory reflects continuous changes of internal competition during decision-making processes. We asked observers to reach towards a unique shape target among distractors. In the low external conflict condition, all distractors were homogenously colored. In the high external conflict condition, one distractor was uniquely colored, which typically results in attentional capture. Regardless of the external conflict condition, we classified trials as either high or low internal conflict based on the magnitude of reaching curvature towards distractor stimuli. Reach trajectory curvature towards distractor stimuli was reduced following high external conflict trials compared to low external conflict trials. This suggests that in accord with previous studies, external conflict results in reduced interference, and thus reduced internal conflict, during the ensuing trials. However, the magnitude of curvature towards distractors was increased following trials with high internal conflict compared to low internal conflict. This demonstrates that in contrast to high external conflict, high internal conflict predicts increased interference in later behavior. Thus, we suggest that external and internal conflict have opposite effects on subsequent behavior.

36.413 Shape beyond recognition: How object form biases spatial attention and motion perception

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It is quite clear that an object's shape provides essential information for recognition, but the role shape plays in recognition should not be taken as evidence that it is not also important in other visual processes. In the current set of experiments, we explored how the shape of randomly generated novel objects affects the allocation of attention and the perception of motion. We first asked a group of subjects to indicate where each shape pointed or directed them (Exps 1,2). The shapes' perceived directionality was used as a variable of interest in subsequent experiments with a new set of subjects. We found that an object's shape automatically guided attention in the direction to which it was judged to point (Exps 3,4). This cueing effect was very rapid and its time course resembled that of exogenous transient visual attention. Participants were also significantly faster and more accurate at judging the direction of apparent motion stimuli when the motion was congruent with the shapes' judged directionality (Exp 5). Interaction with a constantly changing visual world requires observers to efficiently extract information about the current state of the environment to make predictions about where important things will be in the near future. Our experiments indicate that the shape of an object is automatically integrated into such computations, thus biasing where one looks and pays attention. Surprisingly, this shape-induced bias also affects motion processing – a process often studied using stimuli specifically devoid of shape. Here, we show that

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the visual system appears to make predictions about an object's movement based on its shape, demonstrating that an object's shape is involved in more than recognition.

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36.414 Non-predictive cueing produces perceptual enhancement for both endogenous and exogenous attention.

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Exogenous attention is characterized as having a rapid, short lasting, reflexive, involuntary activation, while endogenous attention has a slower onset and longer duration and is engaged voluntarily in a goal directed manner. There is controversy regarding exogenous attention as to whether or not perceptual enhancement (not reaction time) occurs in non-predictive cueing paradigms for accuracy judgments. The present experiment examines two types of attention based perceptual enhancement in a highly demanding divided attention task: location detection, and feature identification. The stimulus locations include one central fixation and six 7.5 degree eccentric locations evenly spaced around the central fixation location. After a non-informative pre-cue is presented at one location, the target, a number, is briefly displayed at some location while distractor letters are displayed at the other six locations. Targets and distractors in the periphery are 100% contrast, black, capital letters (with one being the target number), spanning one degree. The letters and numbers are followed by a new letter mask. Cue to mask onset time is varied from 80 to 520ms, which consists of varied stimulus onset asynchronies (cue to target duration), plus the target stimulus duration and the interstimulus interval between the target offset and mask onset. Exogenous attention is examined for trials with less than the length of time required to voluntarily shift attention via an eye movement (~200ms). Intervals longer than this are believed to utilize endogenous attention. Across all eight subjects, and for the less than 200ms pre-cue to mask intervals, an exogenous capture of attention via a non-predictive peripheral cue improves accuracy for identifying both where the target was presented (location) and what the target stimulus identity was (actual number), even with response bias (from location uncertainty) removed. The same results were observed for longer pre-cue to mask intervals that presumably include endogenous attention effects.

36.415 Awareness of Attentional System and Spatial Judgments

Jean-Paul Noel[1](jnoel@gac.edu), Anthony Mefford[1], Lauren Hecht[1]; [1]Gustavus Adolphus College

Spatial judgments and estimates play a fundamental role in the construction of the visual world. This perception is deeply influenced by the loci of an individual's attentional system and the reference point undertaken when making these estimates. In this study it was hypothesized that exocentric, but not egocentric, spatial estimates would be enhanced by meta-awareness. Furthermore, it was predicted that this effect could be replicated through the process of perceiving oneself from a third person's point of view. In Experiment 1, participants completed the Sustained Attention to Response Task while periodically making depth or segment length estimations. Results confirmed the hypotheses; performance increased for participants in a state of meta-awareness with respect to segment length estimates, but did not for depth estimates. In Experiment 2, a third set of participants estimated distances both egocentrically (i.e., relative to their body) and exocentrically (i.e., relative to an external point), either under natural viewing conditions (i.e., egocentric perspective) or when watching themselves in a virtual reality environment (i.e., exocentric perspective). Results indicated that from an exocentric perspective participants underestimated both egocentric and exocentric distances; however, from an egocentric perspective participants underestimated exocentric distances and overestimated egocentric ones. From these results it can be concluded that although participants do perceive exocentric distance more accurately when conceptually distant from their own attentional system, the processing mechanism underlying this effect is not a purely visual mechanism as the effects were not replicated when participants viewed themselves from a third person's point of view.

36.416 Awareness of cue directionality is important for orienting visual attention, but conscious awareness is not.

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The present experiments investigated the mechanism responsible for the proportion valid cueing effect (i.e., the difference in response times between valid and invalid trials increases in magnitude as the proportion of valid trials increases) in the covert orienting paradigm. This proportion validity effect (PVE) is believed to reflect the involvement of volitional control of visual attention. However, more recently research has suggested that the PVE reflects a form of implicit learning, wherein associations, developed outside of awareness, between the cue and target location determine how attention is distributed. We tested between these two accounts of the PVE by determining whether being aware of a cue's spatial utility influences the PVE using peripheral box cues, central arrow cues and central non-directional shapes (i.e., cues that do not possess inherent directionality). Critically, we manipulated whether participants were aware of the cue-target relations and determined whether this awareness influenced the PVE. Peripheral box cues produced a PVE that was independent and insensitive to participants' awareness of cue-target relations. On the other hand, central cues (i.e., both arrow cues and non-directional cues) produced PVEs that were sensitive to our manipulation of awareness regarding cue-target relations. However, central arrow cues produced a PVE that was independent of awareness, whereas non-directional cues produced a PVE that was dependent on awareness of cue-target relations. Taken together, the present studies have demonstrated that the awareness of the association between cues and target locations does contribute, under some circumstances, to the PVE. However, the extent to which the PVE is influenced by awareness of cue-target relations is dependent on the type of cue used to orient visual attention.

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36.417 When old meets new: Repetition enhances encoding of competing novel items

J. Benjamin Hutchinson[1,2](jhutchin@princeton.edu), Sarah S. Pak[2], Nicholas B. Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Memory can serve as a powerful guide for attention when we encounter objects and environments with which we have prior experience. However, relative to other forms of attentional control based on stimulus salience and intentional goals, memory-guided attention has been relatively less studied. A fundamental question concerns how attention is allocated among items that differ in memory strength, in the absence of differences in salience or goal-relevance. To address this question, we examined how novel scenes were processed in the context of other scenes that had or had not been experienced before. Observers were presented with scenes while performing a cover task (detecting occasional inverted scenes). Each trial consisted of three sequential events: the first two events each contained one scene at fixation, which was either the same across both events or different; the third event contained two scenes placed randomly on either side of fixation, which were either both novel (different-novel and same-novel), or contained one novel scene and the scene from the preceding two events (same-repeated). Observers then completed a surprise memory test for the novel items from the third event of each trial. Notably, novel items from same-repeated and same-novel trials differed only in terms of whether a repeated item was present during encoding. We found that subsequent memory was significantly better for same-repeated than same-novel and different-novel trials (which in turn did not differ). These findings suggest that the presence of a repeated item can bias processing toward novel items competing for attention. Moreover, these results stand in contrast to recent demonstrations that attention is drawn toward items actively maintained in working memory. Thus, novel items may be prioritized over recently encountered items in the absence of working memory demands, allowing other forms of memory to contribute, along with salience and goals, to the control of attention.

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36.418 Changes in Perceptual Sensitivity in an Inhibition of Return Paradigm

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Previous research has illustrated the contributions of a sensory component(s) in inhibition of return (IOR) through manipulations of lower-level sensory stimulus variables (e.g., Guenther & Brown, VSS 2007, VSS 2011; Guenther, Narang, Siddiqui, & Brown, VSS 2009). For example, greater IOR magnitudes have been reported to higher spatial frequency targets (Guenther &

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Brown, VSS 2007; Guenther et al, VSS 2009) and to targets with a ramped presentation (gradual on/off) (Guenther & Brown, VSS 2011). Importantly, these stimulus manipulations held their greatest influence on the reaction times to targets appearing at cued locations. Other research, using short stimulus-onset-asynchronies (SOAs) (e.g., 94-121 ms), has demonstrated transient attention increases spatial (e.g., Yeshurun & Carrasco, 1999) and decreases temporal (e.g., Yeshurun & Levy, 2003) resolution at cued locations. The present experiments tested whether changes in perceptual sensitivity could be observed with the longer timeframes typical of IOR experiments. Temporal and spatial sensitivity were measured at validly and invalidly cued locations in an IOR paradigm using a SOA of 600 ms. Experiment 1 measured the two-flash fusion threshold and found greater temporal resolution at validly cued locations. Experiment 2 measured gap resolution with briefly presented (70 ms) Landolt-square targets and found greater spatial resolution at validly cued locations. Different from experiments with short cue-to-target SOAs (e.g., Yeshurun & Carrasco, 1999; Yeshurun & Levy, 2003), both temporal and spatial resolution were greater at validly cued locations.

36.419 A Gene X Gene Interaction Between COMT and DAT1 in the Attentional Cost of an Invalid Visual Cue

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The reaction time to a simple target can be lengthened reliably (relative to a neutrally cued baseline) by preceding that target with a briefly flashed cue that appears at a different location in the visual field (Posner, Snyder, & Davidson, 1980). The additional steps of disengaging and shifting attention from its current focus to another location require extra time, leading to longer reaction times on invalidly cued trials. Using a sample of 161 observers across the age range from 18 to 61 years, we have previously shown that the additional time required to respond on invalid trials with a cue-target SOA of 150 msec, especially when a low luminance cue is used, depends on an observer's genotype on certain dopaminergic genes (COMT, DAT1; Lundwall, Guo & Dannemiller, 2010). On both of these genes, larger attentional costs are associated with genotypes having less available dopamine. We now show using a novel classification and regression tree (CART) analysis with appropriate 10-fold cross-validation that the effects of these two genes on the attentional costs produced by an invalid, dim cue are not additive. The final decision tree model has two splits. Split 1 divides the complete sample using the COMT SNP: [GG] vs. [AG or AA] with the GG genotype (less available dopamine) showing a mean of 14 msec larger attentional cost. Split 2 then further subdivides only the subgroup of COMT observers having more available dopamine [AG or AA] by their DAT1 genotype: [6R/6R] vs. [5R/6R or 5R/5R] with the 6R/6R genotype (less available dopamine) showing a mean of 16 msec larger attentional costs. It is only the subjects with more available dopamine based on their COMT genotypes whose attentional costs are further significantly differentiated by their DAT1 genotype. These results represent a novel gene x gene interaction in cued visual orienting.

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36.420 The effects of sustained attention, spacing and type of presentation on reading comprehension in adolescents with and without ADHD

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Difficulties in reading comprehension are common in children and adolescents with Attention Deficit/Hyperactivity Disorder (ADHD). Few studies have examined difficulties in reading comprehension in individuals with ADHD. In order to further unravel the underlying mechanisms of reading comprehension difficulties among individuals with ADHD the current study investigated possible relations between sustained attention and reading comprehension among adolescents with and without ADHD. Another goal was to examine the impact of two manipulations on improving reading comprehension: spacing (standard- vs. double-spacing between words and lines) and type of presentation (computer screen vs. hard copy). Eight passages with expository text were introduced to a group of 20 ADHD adolescents aged 16-18 and to another 20 age-matched control participants. All participants were asked to read silently the passage and to answer 10 open comprehension questions. Sustained attention was assessed using the Conjunctive Continuous Performance Test (CCPT). Significant relations were found between sustained attention and reading (number of correct answers and reading duration). In addition, a significant interaction was obtained between presentation-type, spacing and level of sustained attention. Post-hoc tests revealed that for participants with good sustained attention, standard spaced texts displayed on a computer screen produced significantly more correct answers and fewer errors compared to standard spaced hard copy texts. Moreover, for participants with poor sustained attention, spaced text displayed on a computer screen triggered the best comprehension. Based on these results we concluded that difficulties in reading comprehension can derive from deficits in sustained attention. Thus, it is essential to screen for attention deficits when difficulties in reading comprehension occur. In addition, it is recommended to convert printed school materials to computer files that will enable to accommodate the extent of spacing according to the reader's preference.

36.421 The influence of attentional interactions on perceptual processing

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Numerous studies of human attention conducted to date employed central spatially predictive arrows to measure voluntary orienting (e.g., Jonides, 1981). However, since central arrows were recently found to produce orienting even when they are spatially nonpredictive (e.g., Tipples, 2002), it became unclear whether the effects produced by the classic task reflected voluntary attention alone. Using a simple target detection cuing task, Ristic and Kingstone (2006) found that attentional effects of predictive arrows reflected an interaction between reflexive and voluntary orienting rather than voluntary orienting in isolation. However, it still remains unclear whether similar effects would emerge if participants were asked to perform a difficult target discrimination task rather then a simple detection task. To address this, we presented participants with spatially nonpredictive arrows (measuring reflexive orienting), spatially predictive arrows (measuring an interaction between reflexive and voluntary orienting), and spatially predictive shapes (measuring voluntary orienting in isolation). They were asked to discriminate a briefly presented and subsequently masked complex target as quickly and as accurately as possible. Both response time (RT) and accuracy data replicated Ristic and Kingstone (2006) results. Across both measures, predictive arrows produced orienting effects that were larger than both reflexive orienting elicited by nonpredictive arrows and voluntary orienting elicited by predictive shapes. These data solidify the past reports and further suggest that the interactions between the two attentional systems, in addition to enhancing target detection, also lead to facilitation in perception of target's features.

36.422 The Eccentricity Effect of Inhibition of Return Is Independent of Cortical Magnification

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When a target appears in the same location as a previous cue, responding is typically delayed if the cue-target interval is relatively long. This phenomenon is termed inhibition of return (IOR) and has been suggested to reflect an attentional bias against a previously attended location in favor of novel visual space. It has been demonstrated in a recent study (Bao & Pöppel, 2007) that IOR is much stronger in the far periphery than in the perifoveal visual field, and this eccentricity effect is a very stable one that is resistant to practice (Bao et al., 2011). However, one factor that has not been considered in these previous studies is cortical magnification, since identical stimuli were used for different eccentricities. It is known that cortical representation of a unit area in the visual field decreases with eccentricity. Such a basic visual constraint might also account for the eccentricity effect of IOR. In order to clarify this possibility, the present study examined the IOR effects at both 7° and 21° eccentricities with the same spatial cueing paradigm in two critical conditions: in the same-size condition, identical stimuli were used for both eccentricities; in the size-scaling condition, stimuli were scaled according to the magnification factor so that they were larger at 21° than at 7° eccentricity. Compared to the same-size condition, size-scaling eliminated the difference in overall reaction times between the two eccentricities; however, IOR at 21° was still much stronger than that at 7°, showing exactly the same eccentricity effect in both conditions. These results revealed a robust eccentricity effect of IOR which could not be explained by

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the cortical magnification factor. Neural mechanisms underlying this effect are possibly related to subcortical contribution such as the involvement of superior colliculus.

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36.423 Modulation of Neuronal Responses in the Primary Visual Cortex by Exogenous Attention

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Visual perception is subject to the influences of selective attention achieved by voluntary deployment of cognitive resources or triggered by salient and unexpected stimuli. Modulation of visual cortical processing by voluntary or endogenous attention has been extensively studied over the past couple of decades, but little is known about the modulatory effects on responses of visual cortical neurons by involuntary or exogenous attention. In the current study we examined whether exogenous attention could affect responses of neurons recorded by multi-electrode array (Utah Array, Blackrock Microsystems) implanted in the primary visual cortex (V1) of awake monkeys. We used a conventional cueing paradigm whereby a sudden onset of a salient circle cue stimulus (60 ms) was followed by a probe grating stimulus (500 ms) with various luminance contrasts and stimulus onset asynchronies (SOAs). The probe was centered on the receptive fields (RFs) of the recorded neurons while the cue was placed either around the RFs or in the opposite visual field, or at both locations. The animal was doing a simple fixation task. Comparing different cueing conditions, we observed that, at low probe contrasts (5-15%) and with an SOA of about 150 ms, the cue induced a remarkable transient increase of neuronal responses to the probe at the cued location, starting at about 60 ms and peaking around 100 ms after the onset of the neuronal responses to the probe, and lasting about 100 ms. This cueing effect is reminiscent of that documented in psychophysical studies. Moreover, the modulation of the neuronal responses by the cue diminished and disappeared after the animal became accustomed to the stimuli that were task-irrelevant; and the modulation tended to be retrieved by a novel new salient cue. Our observations indicate that exogenous attention triggered by unexpected and salient stimulus significantly modifies visual processing in V1.

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36.424 Visuospatial bias due to stimulus valence requires conceptual processing

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A central proposal of embodied cognition is that perceptual features constitute an essential part of the conceptual representation. Indeed, experimental studies of everyday metaphors such as 'happy is up' and 'sad is down' have revealed how processing concepts can generate spatial biases toward locations compatible with the concepts' meaning. An important question that has remained unanswered is whether spatial association between positive and negative valence (e.g., happy/sad) is in fact conceptual in nature. That is, the observed visuospatial biases may have been simply due to perceived stimulus valence and, as such, non-conceptual. To disentangle conceptual and perceptual processing, we tested the ability of conceptual (affect words) and perceptual (affective faces) stimulus valence in causing visuospatial bias above/below fixation. In each trial, observers were presented with a valenced (or neutral control) stimulus, which was categorized either based on valence (positive vs. negative) or a perceptual feature (upright vs. upside down), followed by a visual target above or below fixation, and made a speeded keypress response to the peripheral target. First, whereas spatial biases were always observed following the conceptual stimuli, with perceptual stimuli, spatial biases were observed only when subjects categorized the faces based on valence. Second, inverting the perceptual (face) stimuli, which induced conceptual ambiguity along the vertical axis (e.g., above fixation is down to an inverted face), reversed the direction of spatial bias, again consistent with the conceptual nature of the effect. Finally, we varied gaze direction of the same face stimuli and found no interaction between the valence-induced bias and the effect of upward/downward gaze cues, suggesting that the mechanism underlying the valence-based spatial bias differs from those responsible for covert shifts of spatial attention. Thus, the perception of positive and negative valence alone cannot generate spatial bias and that conceptual processing is, indeed, necessary for visuospatial biases.

Acknowledgement: NSERC

36.425 Mask-target color congruency enhances object substitution masking in the presence of an attentional control set

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In the object substitution masking (OSM) phenomenon, briefly shown targets can be masked by presenting four small dots that surround the targets but do not touch it (Enns & Di Lollo, 1997). The purpose of the present study was to determine if masking stimuli that are present and visible, but not attended to, can generate OSM. In other words, must the masking stimuli be attended to in order for OSM to occur? To accomplish this, we used top-down attentional control settings, which have profound effects on what sort of stimuli capture attention; stimuli that have features that match a target capture attention while stimuli that mismatch with target features are ignored. In our experiment, subjects were told to locate a target (distinguished by color from distractors) and to identify a feature on the target, thus creating an attentional control set for that color. Four-dot masks with either the same (mask-target match) or different color (mask-target mismatch) as the target were presented at SOAs ranging from -144 to 144 ms. When subjects searched for green targets, masking was enhanced if the four-dot mask was also green (match) as opposed to red (mismatch). This difference was largest 48 ms after target offset. Also, there was no difference between color match and mismatch masks when there was no attentional control set for green. Thus, the present results cannot be attributed simply to mask-target color congruency effects but rather the interplay of attention and vision. Specifically, our results show that masking is considerably enhanced when the four-dot mask falls within the subject's attentional control set. Overall, this suggests that object substitution masking is mediated partly by attention and subject to top-down attention control.

Binocular vision: Rivalry II

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

36.427 Perceptual Filling-In During Binocular Rivalry Relates to Variation in Working Memory Capacity

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In binocular rivalry, perception typically alternates between each eye's image, but percepts containing elements from both images are also possible. This study uses "patchwork" stimuli, in which each eye receives a complementary patchwork of two rivalrous images. Patchwork stimuli can evoke percepts with interocular grouping (complementary patches from each eye combine to give a coherent whole), and also percepts with filling-in (a feature that is physically present at one location perceptually "fills" neighboring locations), revealing a possible role for cognitive processes in rivalry (Kovács et al., 1996). The current study found that individual differences in working memory capacity (WMC) are related to the frequency and stability of perceived filling-in with rivalrous stimuli. WMC reflects the ability to maintain relevant representations while simultaneously inhibiting irrelevant representations. It is related to perceptual stability of an ambiguous figure (Allen et al., VSS2011), but its role in binocular rivalry has not been established. Forty-three participants viewed images haploscopically that contained a 4x4 array of dots equiluminant to a yellow background (after Kovács et al., 1996). In the CLASSIC condition, each eye's image had either all red dots or all green dots. In the PATCHWORK condition, each eye's image contained half red and half green dots, with different-colored dots presented in complementary locations in each eye. WMC was assessed for each participant using the RSPAN task. WMC was correlated with the proportion of time participants reported filling-in (solid yellow percept) in both the CLASSIC ($r=0.36$, $p<0.02$) and PATCHWORK ($r=0.31$, $p<0.05$) conditions. Moreover, the stability of this percept was correlated with WMC in the CLASSIC condition ($r=0.30$, $p<0.05$ a priori one-tailed test). Other results were inconsistent with the possibility that Troxler's fading caused

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these correlations. These results suggest WMC is related to a coherent perceptual experience during rivalry at retinotopic locations where there is interocular conflict.

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36.428 Advantage of fearful faces in breaking interocular suppression is preserved after amygdala lesions

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The amygdala is thought to play a key role in modulating cognitive processes including the recognition, learning, and appraisal of emotionally-salient events, according to previous neuroimaging and lesion studies. What remains to be determined, however, is the amygdala's role in the enhanced or biased perception of affectively-laden stimuli. Recently, Tsuchiya et al. (2009) reported that a patient with bilateral amygdala lesions showed intact rapid detection of fearful faces under interocular suppression. We have replicated and extended that finding using a large cohort of adult patients (n=27) who had undergone resections of either their left (n=12) or right (n=15) amygdala. We used the same paradigm as our previous study (Yang et al., 2007) in which upright and inverted faces of neutral, happy, or fearful expressions were pitted against a dynamic, high contrast, noise display that evoked potent interocular suppression. Observers performed a 4-alternative forced-choice discrimination task, quickly indicating the location of the face stimulus as it emerged from suppression. Replicating previous findings, we found that fearful faces broke suppression more quickly compared to neutral faces ($t(36)=4$, $p<.001$) and happy faces ($t(36)=6.1$, $p<.001$). Importantly, the pattern across emotion conditions was not significantly different between patients and 10 healthy age-matched controls ($F(2,70)=0.05$, $p>.05$). Neither were there significant differences in performance between left and right amygdala lesion patients ($F(2,50)=0.5$, $p>.05$) nor any significant correlations between the size of intact amygdala tissue and behavioral performance. Our results along those of Tsuchiya et al. (2009) and Peich et al. (2010) suggest that the amygdala is not essential for enhanced detection of fear-related visual stimuli.

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36.429 Enhanced Attentional Control of Binocular Rivalry in Action Video Game Players

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Attention serves a crucial role in a wide range of visual functions, allowing for the selective and enhanced processing of attended stimuli. Recent research indicates that attention can also modulate dynamics of binocular rivalry (reviewed in Dieter & Tadin 2011; Paffen & Alais 2011). Intriguingly, one consistent finding is that observers are unable to voluntarily bias alternations in favor one of the rival stimuli (Meng & Tong 2004) unless they are performing a demanding attentional task (Chong et al. 2005). One possible explanation of this finding is that typical observers have little experience voluntarily selecting between monocular representations and are generally poor at attentional control over early visual processes, especially in the absence of a behaviorally relevant task (Dieter & Tadin 2011). Given this hypothesis, it is possible that individuals who have a great deal of attentional training may overcome this limitation in attentional control of rivalry. One such group is action video game players (VGPs), who show a multitude of benefits in visual attention (Bavelier et al., 2011). We tested experienced VGPs and subjects who had no experience with action video games (NVGP) in a battery of binocular rivalry tasks. Individuals either (1) passively viewed rivalry, (2) attempted to hold one of the two rival images dominant as long as possible, or (3) completed a demanding behavioral task on one of the rival images. Results showed that VGPs were able to increase the predominance of the attended rival target even in the absence of a behavioral task ($p<0.01$). In addition, the magnitude of attentional control while performing a demanding behavioral task was greater in VGPs than NVGPs ($p<0.01$). Taken together, these results demonstrate that extensive training of attentional mechanisms can lead to increased voluntary control over binocular rivalry dynamics.

36.430 Is attention modulation of binocular rivalry identical for eye-based and stimulus-based competition?

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Binocular rivalry is characterized by perceptual switching between monocular images when quite dissimilar stimuli are presented dichoptically. How the visual system can effectively suppress one visual input from awareness is still debated. Two main hypotheses have been proposed: the first posits that rivalry could results from low-level competition between the eyes, whereas the second suggests that the nature of the competition is perceptual, i.e., between the stimuli, whereby high-level visual areas play a crucial role. Recent research interest has been deployed to study the role of attention in resolving binocular rivalry competition. Although some evidence indicates that selective attention can bias dominance phases, whether or not such an attention modulation is specific to one type of visual competition (eye- versus stimulus-based) is unknown. To address this issue, we manipulated the stimulus size (1.4° or 10° diameter with a constant spatial frequency duty-cycle) of two rival (± 45°) gratings to preferentially recruit different levels of competition (Bonneh et al., 2001). Stimuli were presented through stereoscopic goggles using a swapping paradigm to better dissociate eye- and stimulus-based rivalry. While indicating their percepts (stability/dominance, swapping or ambiguity) through different responses keys, observers (n = 11) viewed the stimuli either passively or by focusing their attention as long as possible on the +45° grating stimuli. Catch trials were used in order to detect any response bias that could be induced by attention instruction. As expected, ANOVAs revealed that, in the passive condition, phases of stability were significantly ($p<.05$) larger for the larger stimuli whereas swapping perception was significantly predominant for the smaller stimuli. In the attention condition, dominance duration was significantly higher for the attended stimulus than for the other but only for the larger stimuli. These results suggest that higher visual areas are preferentially modulated by endogenous attention during binocular rivalry.

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36.431 Color-grapheme synesthesia affects binocular vision

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In color-grapheme synesthesia, non-colored graphemes are perceived as being inherently colored. In recent years, it has become evident that synesthesia-inducing graphemes can affect visual processing in a manner comparable to real, physical colors. Here, we exploit the phenomenon of binocular rivalry in which incompatible images presented dichoptically compete for conscious expression. Importantly, this competition only arises if the two images are sufficiently different; if the difference between the images is small, the images will fuse into a single, mixed percept. We presented synesthetes and pair-matched controls with different achromatic graphemes (e.g. the digit 2 for the left eye and the digit 5 for the right), which did not lead to significant periods of binocular rivalry in controls. However, achromatic graphemes that induced synesthetic color percepts (i.e. only in synesthetes) evoked significant periods of binocular rivalry. That is, compared to achromatically perceived graphemes, synesthesia-inducing graphemes increase the predominance of binocular rivalry over binocular fusion. This finding shows that the synesthetic color experience can provide the conditions for evoking binocular rivalry, much like stimulus features that induce rivalry in normal vision. In addition, the results suggest that the synesthetic color experience is interacting at the stage where monocular visual information from two eyes leads either to binocular fusion or binocular rivalry.

36.432 The role of parietal visual cortex in perceptual transitions during bistable perception

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Several imaging studies in humans have shown the involvement of a frontoparietal network of cortical areas in perceptual transitions during bistable perception. To investigate further the possible role of parietal visual areas in perceptual alternations, we recorded extracellular neural activity in the lat-

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eral intraparietal area (LIP) of the rhesus macaque. The subject was initially presented with congruent patterns to the two eyes. Then the stimulus was switched for either one or both eyes (binocular flash suppression versus physical alternation), both resulting in perception of the newly presented stimulus. The recorded cells typically showed an initial burst of activity at stimulus onsets as well as stimulus switches. In contrast to previous reports by a number of fMRI studies, we found strong transient activity during physical alternations at the single cell level. This signal was also present during binocular flash suppression but to a lesser extent. Importantly, the amplitude of the signal dropped substantially in control conditions where physical changes were introduced in the stimuli but did not induce concomitant changes in perception. The transient response of the recorded neurons was followed by a tonic response which exhibited independent dynamics. Interestingly, this sustained activity was significantly lower during incongruent versus congruent stimulation. We conjecture that areas at the high end of the dorsal pathway might be involved in multistable perception in a different way in comparison with feature and object selective areas of the ventral pathway. The transient signal recorded in LIP neurons during perceptual transitions could potentially trigger reorganization of activity in constellations of feature selective neurons in the ventral pathway. In addition, the suppression of the sustained activity in LIP during incongruent stimulation may reflect inhibitory processes involved in the resolution of conflict between the two stimuli or indicate a failure to bind the sensory input into a coherent percept.

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36.433 **Normalization regulates competition for visual awareness**

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The notion that binocular rivalry and attention are intertwined has been debated for over a century, and some have gone so far as to directly attribute perceptual alternations in rivalry to switches in attention. Here, we develop and test the related idea that attention and rivalry reconcile competing visual information via a common computational framework, one in which modulation of awareness through rivalry impacts attentional modulation. To pursue this idea, we measured psychometric functions for a variable contrast stimulus presented to one eye under dominant and suppressed states of rivalry, and manipulated the size of the competing stimulus presented to the other eye. The resulting contrast psychometric functions provide behavioral measures that scale proportionally to the signal-to-noise ratio of the underlying neural contrast response functions. Those functions reveal a pattern of gain changes consistent with a model of rivalry in which attention interacts with normalization: whereas a large competing stimulus caused only a contrast gain reduction, a smaller competitor caused reductions in both the contrast gain and response gain. We propose a computational framework whereby competition between sensory representations is governed by a common mechanism: normalization. In this framework, attention and rivalry are intricately intertwined, whereby visual awareness during dominance phases of rivalry dictates what receives attention and what does not

36.434 **Unconscious processing of affordance information of tool images**

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An object's affordance is a critical property that our visual system is able to extract, for which the dorsal pathway presumably plays a key role. A recent study showed that viewing manipulable objects such as tools induces the neural activation of posterior parietal areas. Moreover, this neural activation is observed even when visual awareness of presented object image is suppressed by continuous flash suppression (Fang & He, 2005; Almeida et al., 2008; Almeida et al., 2010). However, it is not clear what specific visuomotor information in the tool images drives the activation in the dorsal area. In the present behavioral study, we investigate the functional relevance of the information processing of tool images in the absence of awareness. Using a priming paradigm, observers distinguished the orientation of tools (appropriate for left vs right handed grip) for briefly presented tool images following the presentation of visually suppressed primes using continuous flash suppression technique. The invisible primes also consisted of tools in the left or right handed orientations, thus the prime and the target tool images could be congruent (Left-Left or Right-Right handed grip) or incongruent (Left-Right or Right-Left handed grip) in orientation. Results show that observers responded faster in the congruent than in the incongruent conditions, and this effect is primarily observed in the right-handed responses. Thus even without overt recognition of presented tools, their action affordance could be registered and processed in the brain, likely in the dorsal pathway.

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36.435 **Object-level properties influence the temporal dynamics of binocular rivalry: a test using Chinese characters**

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During binocular rivalry, two dichoptically presented images alternate in perceptual dominance. The perceptual switching rate of binocular rivalry can be influenced by many factors, including well-characterized low-level image factors such as contrast, size, and eccentricity, as well as an individual's genetics. It is less understood how and why high-level object properties influence the dynamics of binocular rivalry. Previously we have shown that the lateralized processing in the brain for different categories of objects (e.g., faces vs. words) influences their relative dominance time when competing stimuli are presented in the left or right visual field (J Vis, 2010 10(7): 332). In the current study, we investigate the effect of object representation on the temporal dynamics of binocular rivalry. Specifically, two Chinese characters were used in one condition and two matched non- characters were used in the other condition. The size of each stimulus was 1 degree of visual angle and a small fixation point was placed in the center of each image. Subjects recorded their perception with key presses. Results show that the switch rate of rivalry between real Chinese characters was slower than that between matched non-characters. It is likely that the different switching rates for real characters vs. non-characters reflect their differential level and depth of representations in the brain. We suggest that during binocular rivalry, with low-level image factors matched, it takes more neural effort to overturn the dominance of a more extensively represented image (e.g., a real character) than an image with less extensive representation in the brain (e.g., a non-character).

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36.436 **Unattended and crowded dochoptic stimuli lead to mixed and patchy percept**

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Previously we found that a physiological signature of binocular rivalry disappeared when attention was diverted away from the competing stimuli (Zhang et al., 2011). However, the perceptual status of the dichoptic stimuli in the unattended condition remains elusive. In the present study, we used a novel behavioral paradigm to investigate the perceptual status of dichoptic stimuli in both the unattended and crowded situation. At the beginning of each trial, a pair of orthogonal gratings was dichoptically presented 2.5 degrees below the fixation, and subjects pressed a button as soon as one of the stimuli became exclusively dominant. Then the dichoptic stimuli were crowded by a set of 4 binocular flankers and subjects started performing a demanding RSVP task at fixation. When the RSVP task stopped, the flankers were removed and the dichoptic gratings remained on the screen for anther 200ms for subjects to report their perceptual status. Compared to the attended condition during which subjects attended to the dichoptic stimuli without flankers, subjects reported much more mixture (patchy) perception in the unattended condition. In a second experiment with no fixation task, subjects directed their attention to the crowded display with the dichoptic stimuli centered at 4 degrees below the fixation. Similarly, in each trial subjects pressed a button to indicate the one of the stimuli was exclusively dominant, and the binocular flankers were immediately added. Following a fixed amount of time, the flankers were removed with the dichoptic stimuli stayed on screen for another 200ms. Subjects again reported more mixture perception compared to the no flanker condition. These results suggest that exclusive rivalry could not be maintained when attention is prevented from reaching the dichoptic stimuli.

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Perceptual learning: Space and time

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

36.439 Perceptual Learning in Jigsaw Puzzle

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Perceptual systems pick up information about the structure of patterns in problem solving and learning situations (Gibson, 1969; Kellman, 2002). Humans show experience-induced changes -- perceptual learning -- in picking-up information in complex tasks such as chess. Recent work suggests that such expertise can be accelerated by perceptual learning modules (PLMs) based on many short speeded classification trials (e.g., Kellman, Massey & Son, 2010). We tested two kinds of PLM interventions for a jigsaw puzzle task. In a pre-test and post-test, participants were required to make a 4 AFC to judge which puzzle piece could be connected to the target piece of jigsaw puzzle with 5 fine-art scenes. The two PLM interventions, given between pre-test and post-test, each consisted of 400 trials of 2AFC judgment with geometrical patterns, requiring either (a) connection judgments similar to those in the pre- and post-test, or (b) same-different judgments in which participants chose the same piece as the target. Both PLM interventions produced significant improvements between pre-test and post-test in accuracy (correct response rate) and in fluency (reaction time). Especially large effects of the interventions were found for the fluency measure. These results suggest that (a) perceptual learning facilitates pick up of complex relations between target and test pieces, b) that these improved abilities transferred to novel situations, and that (c) fluency in pick up of complex relations can be markedly improved in only a few hundred trials.

36.440 Video game training improves visual cognition: a multiple game study

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Although recent research indicates action video game playing can improve performance on visual cognitive tasks, results using other video games have been equivocal. We compared visual cognitive performance on five groups before and after 20-hours of training using either action video games or four games with varying visual demands: hidden object, match-3, Sims, or spatial memory games. The test battery included tasks measuring attentional blink, complex verbal span, a visual short term memory task, and a visual search and spatial working memory dual task. These tasks contain cognitive demands that are both similar and dissimilar with the video games to determine near and far transfer effects respectively. We expected that participants would demonstrate near transfer far more commonly than far transfer. Participants trained using mobile gaming platforms with much smaller screen sizes than desktop-computer screens used in previous studies. The results replicated previous findings, showing that action games improved visual working memory capacity, filtering of distractors, and eliminated attentional blink. For other games, near transfer effects for the match-3, hidden-object and spatial memory groups were demonstrated by improved visual search scores. Further, the hidden-object game training significantly improved spatial working memory. For far transfer, action, match-3 and Sims game groups significantly improved in complex verbal span performance. These far transfer improvements may be due to planning and strategizing elements within these games that may lead to improvements to higher-order executive processes. Our results demonstrate that playing visually and cognitively demanding videogames can lead to lead to both selective, and more widespread changes in cognition, but the specific improvements depend on the type of behavior that is trained by the videogame. Training tasks that place demands on higher-order cognition may be important for far transfer to occur.

36.441 Action videogame playing improves visual-motor control before it improves vision

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Although action videogame playing can benefit basic visual functions such as contrast sensitivity (Li, Polat, Makous, & Bavelier, 2009), it remains in question how action videogame playing affects visual-motor control, the skill most exercised during videogame playing. We therefore examined the effect of action videogame training on a closed-loop manual control task in which participants used a joystick to keep a Gaussian blob (8.7°) centered on a 110° x 94° display as its horizontal position was perturbed by the sum of seven harmonically-unrelated sinusoids (0.1-2.19 Hz). Six naïve Non-Videogame Players (NVGPs, 3 males, 3 females) were trained with an action videogame (Mario Kart Wii, Nintendo), and five naïve NVGPs (2 males, 3 females) were trained with a non-action, strategy videogame (Roller Coaster Tycoon III, Atari) for 1-2 hours a day for 10 hours in total. Their performance on the manual control task was measured before the training, after 5-hour training, and at the end of the full 10-hour training, while their contrast sensitivity function (CSF) was measured before and after training. For the manual control task, 90 s time series of blob position and joystick displacement were Fourier analyzed and averaged across six trials. For the group of NVGPs trained with the action videogame, RMS error decreased by 14% (SD: 8%) after 5-hour training and by 20% (SD: 6%) at the end of the 10-hour training, and frequency response analysis showed an increase in overall control response (gain) by 24% (SD: 11%) after 5-hour training and by 32% (SD: 15%) at the end of the 10-hour training. In contrast, no change of RMS or gain was observed for the group trained with the non-action videogame. For both groups, no change in CSF was found. Our results show that action videogame playing can improve visual-motor control without affecting basic visual functions.

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36.442 Fast Task-Irrelevant Learning: How different types of attention and task-relevance impact memorization of rapidly presented images.

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Task-irrelevant learning (TIL) refers to the phenomenon where the stimulus features of a subject's task are learned when they are presented at times of behavioural relevance. Here we present results of a recently discovered fast-form of TIL (fast-TIL), which can be observed with as little as a single trial of exposure. We first observe that a sudden onset of a behaviorally relevant event disrupts fast-TIL. One hypothesis is that the sudden onset of the relevant event exogenously draws attention, disrupting TIL. This result raised the question of the role of attention in fast-TIL: does attention modulate fast-TIL, and how? Posner proposed three different networks of attention: orienting, alerting and control. To study the role of orienting and alerting in TIL, we conducted different studies. First, experiments of fast-TIL using arrows as behavioral relevant targets were conducted to study the role of orienting of attention. The results indicated that attentional orienting aids in the memorization of images presented at times with the relevant target event. These results support the hypothesis that the orienting attentional system plays a role in TIL. Secondly, two experiments of fast-TIL were conducted in which the attentional state of participants was manipulated by using an alerting cue. The results indicated that an alerting cue plays a significant role in the encoding of images presented at times with the relevant events, cue and target, but in different ways. The presentation of an alerting cue increased the ability to recall information presented after this signal. However, memorization of cue-paired stimuli was suppressed. These results support the hypothesis that the alerting attentional system plays a role in TIL. Overall, our results demonstrate that multiple aspects of attention can operate in a beneficial manner in TIL, but that all relevant events are not equal in their impact on encoding processes.

36.443 Learning to predict: unsupervised training of temporal sequences

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Experience and training are known to facilitate our ability to extract regularities that are critical for visual recognition. However, the brain mechanisms that enable us to exploit previous knowledge to predict upcoming events remain largely unknown. Here, we combine behavioral and fMRI measurements to investigate the neural mechanisms that mediate predictive learning. Human observers were presented with a temporal sequence

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of leftwards vs. rightwards oriented gratings followed by a test grating. We asked observers to judge whether the orientation of the test stimulus matched their prediction based on the preceding sequence. Observers were trained on two structured sequences that gave rise to opposite predictions but were composed of common temporal segments (e.g. pairs of orientations). To ensure judgments were not based on memory, the orientation of the first stimulus in the sequence was randomly selected and the last three stimuli were the same for both sequences. Unsupervised training (three to five sessions of exposure to the sequences without feedback) improved observers' performance for structured, but not random, sequences. This predictive learning generalized to a) sequences with the same temporal structure but different grating orientations and b) sequences with the same temporal segments but presented in a different order. After training, we measured fMRI responses, contrasting activity from the trained structured sequences against random sequences. We found significantly stronger activations for structured than random sequences in visual areas and a network of frontal, medial temporal and subcortical (i.e. thalamic) regions. These results suggest that training enhances our ability to exploit temporal regularities for predicting future events. This predictive learning ability is mediated by a network of brain areas known to be involved in associative learning that may, in turn, modulate early visual processing.

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36.444 **Failure to learn unusual optimal points of fixation during face identification**

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Introduction: Strategic deployment of eye movements is critical for maximizing perceptual performance in many tasks, ranging from visual search (Najemnik & Geisler, 2005) to face recognition (Peterson & Eckstein, 2011). Little is known about how these eye movement strategies are learned. Here, we assessed the human ability to learn optimal eye movement strategies with unusual face stimuli. Methods: We first measured observers' preferred point of fixation for face recognition by having observers identify briefly presented faces. Observers then ran 1600 trials identifying four morphed faces which, unknown to the participants, contained all discriminating information within the mouth area. This study interleaved free eye movement trials and forced fixation trials where observers were required to maintain fixation at their preferred saccadic landing point. Next, we measured a visibility map by having observers identify the morphed faces while maintaining fixation at 5 specific locations. Finally, observers completed 500 additional trials in which free eye movement and forced fixation trials were interleaved. Results: Observers were classified into two groups: learners (who showed a large and significant increase in performance in both fixed and free conditions) and non-learners. Learners, unlike non-learners, also exhibited a significant downward shift in saccade landing location across trials; however, performance improvements were similar for the free and forced fixation conditions. Visibility measurements showed that while eye movements migrated downward to the nose tip, they did not reach the optimal fixation point (center of the mouth). Subsequent learning sessions after exposure to various points of fixation resulted in both initial learners and non-learners executing optimized eye movements that maximized performance. We suggest that humans' initial failure to learn optimal fixation strategies with unusual faces arises from a difficulty to break away from over-practiced eye movement strategies that are optimal across an ensemble of regular faces but not for unusual faces.

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36.445 **There is more to statistical learning than associative learning: Predictable items are enhanced even when not predicted**

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Statistical learning refers to automatic and unconscious learning of associations between stimuli based on their repeated temporal and/or spatial relationships. Previous studies that have used an RSVP detection paradigm have demonstrated that subjects respond more quickly to target stimuli when they follow stimuli to which they have been temporally associated. These results were interpreted as reflecting priming of 2nd items by 1st items within a learned pair. However, an alternative interpretation is that 2nd items are more easily detectable in general after learning. To test between these two competing hypotheses, we conducted a visual statistical learning experiment (Experiment 1) in which subjects' reaction times were measured in response to 2nd items when they were preceded by associated items (match condition) vs when they were preceded by non-associated items (mismatch condition). Our results showed that subjects responded with faster reaction times to 2nd items of pairs compared to 1st items in both the match and mismatch conditions. These data suggest that the reaction time results observed in statistical learning studies of this kind are not exclusively due to associative learning. We conducted two follow-up experiments to examine whether the temporal predictability of the 2nd items was leading to an increase in their general saliency. Specifically, after inducing statistical learning by exposing subjects to temporally associated visual pairs, we tested their ability to detect the stimuli in a visual search task (Experiment 2) and a masking task (Experiment 3). Our results indicated that subjects had a significant change in response bias and a trend in increased detection sensitivity for 2nd items compared to 1st items. Altogether, these results suggest that statistical learning leads to representational changes for the individual items and that previous findings of associative effects are at least partially confounded by increased sensitivity and perceptual biases for statistically reliable stimuli.

36.446 **Do Infants Demonstrate Perceptual Learning?**

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Aim: Mass educational/entertainment media is currently directed at infants (e.g., "Baby Einstein"), yet the consequences on perceptual development are unknown. Here, we asked whether exposing 3-month-olds to Chromatic (Chrom, red/green) and Luminance (Lum, dark/light) patterns affects their sensitivity to these stimuli. Methods: The stimuli were Lum and Chrom gratings (0.27 cpd; 4 Hz). The experiment took place over 3 days: Day 1: Pre-exposure testing, Day 2: Video-Exposure (10-minute video; exposure confirmed with fixation monitoring), Day 3: Post-exposure testing. Infants were randomly assigned to groups: Lum-Exposed (n=12), Chrom-Exposed (n=12), and No Exposure (listened to music, n=11) for a "control" measure of first/second test performance change. On Days 1 and 3, contrast sensitivity was measured using FPL and interleaved Lum/Chrom staircases. Post/Pre-Exposure log Sensitivity Ratios (SR) were calculated, with SR>0 reflecting improved sensitivity between first/second test. As a "boredom" control, we measured looking times for Lum vs. Chrom stimuli presented side-by-side. Post/Pre-Exposure log Preference Ratios (PR) were calculated, with PR>0 reflecting increased looking to the exposed stimulus. Results: Exposure to a Lum video resulted in changes to SRs that differed for stimulus type, as evidenced by a significant interaction (p=0.05) between group (Lum-exposed vs. Controls) x stimulus type (Lum vs. Chrom). This was driven by an improvement in Chrom and a decrement in Lum sensitivity. This effect is unlikely to be due to boredom with the Lum stimuli, since PRs for Lum vs. Chrom stimuli did not change as a result of exposure. No main effects or interaction were seen in infants exposed to the Chrom video. Conclusions: The selective performance decrement in 3-month-olds may be consistent with perceptual deterioration seen in adults, following practice, not explained by boredom or fatigue (Mednick et al, 2005). These results join the trove of controversial evidence pointing to the ineffectual, even negative, effects of television during infancy.

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36.447 **Individual variability in learning ability across the lifespan.**

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Learning is shown to play a key role in facilitating performance in a wide range of perceptual skills in both young and older adults. But why do some people learn better or faster than others? Here, we investigated whether individual variability in cognitive functions accounts for differences in learning ability in young and older adults. We tested the ability of young (n=30, 18-30 years) and older (n=30, 65-90 years) adults to discriminate radial and concentric global forms (Glass patterns) embedded in background noise before and after training. We manipulated a) the amount of background noise, and b) the similarity between global forms, using linear morphing between concentric and radial patterns. We trained participants at either fixed or variable amounts of background noise across trials for four to five daily sessions. In addition to this perceptual learning task we tested a range of cognitive abilities, including cognitive inhibition, visual

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short term memory, selective and divided attention. Our results showed that learning improved performance (i.e. decreased discrimination thresholds) in both young and older adults. Correlating performance in the cognitive and perceptual learning tasks showed that high performance in cognitive inhibition correlated significantly with threshold reduction after training. Interestingly, learning performance correlated significantly with performance in attentional tasks when observers were trained with variable amounts of background noise across trials. In contrast, for fixed amounts of background noise, learning performance correlated significantly with visual short term memory. Finally, threshold reduction correlated more strongly with performance in attentional tasks for good learners (i.e. individuals with high learning performance), while performance in memory tasks for weak learners. Our findings suggest that a) performance in attentional and memory tasks may account for individual variability in learning, and b) task context determines which cognitive abilities are critical for visual learning across the lifespan.

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36.448 **Pupil diameter changes non-monotonically with perceptual learning**

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Pupillometry has been almost completely neglected in perceptual learning research despite the well documented correlations between pupil size and cognitive variables such as mental effort. We explored whether and how pupil size varies with perceptual learning of motion direction discrimination. Method: The stimuli were moving filtered-noise textures with constant mean luminance presented at eccentricity 7 deg either to the Left or Right of fixation. Twenty one observers discriminated motion directions that differed by either 8(Easy) or 4(Hard) degrees. Each participant (N=21 counterbalanced in 4 groups) trained on a particular combination of difficulty and position on days 2 through 5, and was tested on all 4 combinations on days 1 and 6. The pupil diameter was recorded with an Eyelink 1000 eye tracker in a darkened room with consistent ambient light. It was averaged across all fixations within a trial and then normalized across trials within subjects. Results: The group-averaged d' increased monotonically (Δd'=1) and the reaction time decreased monotonically (ΔRT=200 ms) during training. However, the pupil diameter changed in a non-monotonic inverted-V pattern across sessions (Takeuchi et al., 2011). Moreover, its time course was modulated by task difficulty – the pupil size peaked on Day 3 in the Hard-training group and on Day 4 in the Easy-training group. Switching to the untrained retinal position increased pupil size in the Hard-training group. There was also a pronounced decrease in pupil diameter within each session, replicating the common time-on-task effect. The individual differences in pupil diameter and overall d' were positively correlated (r=.4 calculated on Day 1 when all groups followed an identical protocol). Conclusion: The inverted-V pattern in the pupil data is qualitatively different from the monotonic learning curves in the behavioral data. This suggests that pupillometry captures a unique aspect of perceptual learning, modulated by task difficulty and stimulus specificity.

Perceptual learning: Sensory plasticity/ adaptation

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

36.451 **Distinct mechanisms control contrast adaptation over different timescales.**

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Exposure to a high contrast pattern reduces visual sensitivity to similar patterns. Such contrast adaptation becomes longer-lasting as the inducing period lengthens. This might occur because, over time, either a single mechanism controlling adaptation gains strength, or additional mechanisms operating over longer timescales become active. We resolved this debate using a "deadaptation" procedure to reveal separate mechanisms acting at distinct timescales. Subjects adjusted an adapted sinusoidal grating, presented in either the upper or lower visual field, to match the appearance of a 0.25 contrast unadapted grating, presented in the opposite visual field. The patterns were presented for 200 msec, following a 1400 msec adapting grating presentation. The experiment had four stages: First, a 0.25 contrast adaptor was presented during 2 minutes of baseline measurements. This was followed by 5 minutes presentation of high contrast (0.80) adaptation, then 40 seconds of low contrast (0.0625) adaptation, and a final 2 minutes of 0.25 contrast adaptation. The 5 minutes of high contrast adaptation showed strong effects. Subjects increased the contrast of the adapted pattern substantially to match the unadapted pattern (by 0.17 above baseline measurements). These effects were completely eliminated by the brief low contrast adaptation (deadaptation). However, in the final 0.25 contrast adaptation period, effects of the high contrast adaptation gradually reappeared (asymptoting at 0.045 above baseline, p <0.01). A single mechanism cannot account for such spontaneous recovery of adaptation. The simplest explanation is that deadaptation produced a negative effect in shorter-term mechanisms that masked ongoing adaptation in longer-term mechanisms. Once the adapting contrast returned to baseline, the short-term negative effect decreased quickly, allowing the ongoing longer-term effect to be unmasked. We found similar results using contrast detection and tilt-after-effect paradigms. Distinct mechanisms operating over different timescales may give vision needed flexibility in adjusting to constantly changing environments.

36.452 **How the perceptual template expands across the visual field with learning: a classification image study.**

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Perceptual learning changes the way the visual system samples and integrates the stimulus information. Efficiency of the internal weighting of the stimulus information (perceptual template) has been found to improve, explaining at least partially the performance improvement. However, less is known about the principles that determine how learning changes the template. Here we use classification image (CI) method to investigate how the tuning of observer's template change in line orientation discrimination task. Previous studies (Li, Levi & Klein, 2004; Dobres & Seitz, 2010) have found that observers initially use mostly foveal information, while as learning progresses the template spreads towards the periphery. However, the stimuli in these studies have also had the highest signal to noise ratio (SNR) in the fovea, leaving two potential theories for the change: 1) a spread from the fovea to the periphery; 2) a spread from the stimuli components with the highest SNR. Here, stimuli were noisy peripheral oriented lines where the SNR was inversely related to the distance from the center. Lines were composed of 16 windowed checkerboard elements (width 0.75°, spacing 1.0°) displayed at 10°. Eye tracking was used to ensure central fixation. Underlying orientation of the lines was varied using method of constant stimuli, and positional noise (Li, Levi & Klein, 2004) was added to perturb the element locations. Observers discriminated the line orientation using a rating scale yes-no task (800 trials / session, 5 sessions). All observers showed steady improvement in the discrimination performance. CIs show that initially observers used a sub-optimal strategy, relying almost solely on the top and bottom parts of the stimulus where the SNR was highest. During the learning observers tuned their templates, extending the weighting especially to adjacent locations close to the initial hotspot. Template change was most pronounced in observers having the worst initial performance.

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36.453 **Dynamic coding of sinusoidal brightness variation in time**

Arni Kristjansson[1](ak@hi.is); [1]School of Health Sciences, University of Iceland

The range of variation in environmental stimuli is much larger than the visual system can represent. It makes sense for the system to adjust its responses to the input statistics of the environment such as when our pupils contract to limit the light entering the eye, which comes at a cost to the representation of lower luminance levels. Previous evidence indicates that the visual system increasingly centers responses on the mean of the visual input and scales responses to its variation during adaptation. Here we tested to what degree adaptation to a brightness-varying stimulus will result in such adjustment of responses. The first two experiments tested whether the sensitivity to change in the amplitude and the mean of a large (9.6 deg) patch which varied sinusoidally in brightness over time (0.6Hz) would increase or decrease. In the third and fourth experiments this was tested for a dynamic peripheral stimulus (random patches moving around a circle on the screen) to test to what extent the effects uncovered in experiments

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1 and 2 were driven by retinotopic mechanisms. Sensitivity to changes in mean and amplitude of the temporal brightness variation increased sharply the longer the adaptation to the variation both for the large patch as well as during variation of the random patches. The results show that adaptation to brightness variation leads to increased sensitivity to temporal brightness variation for both central and peripheral presentation.

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36.454 **Reliability-based calibration of vision and proprioception following exposure to in-depth prismatic distortion**

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We performed an experiment to determine the relative contributions of vision and proprioception to sensory adaptation to in-depth prismatic distortion. In-depth localization tests were performed before and after a 10-min period of left-hand pointing during which participants wore a pair of 5-PD base-out prisms that decreased apparent distance. Visual localization was measured using open-loop pointing to visual targets with the right hand. Proprioceptive localization was assessed using pointing to the left hand with the right hand, eyes closed. On average, subjects showed a significant 48-mm visual aftereffect ($p<0.001$) and a significant 6-mm proprioceptive aftereffect ($p = 0.03$). The visual aftereffect was significantly larger than the proprioceptive aftereffect ($p<0.0001$). Both aftereffects were in the expected direction. The mean relative contributions of vision and proprioception to sensory adaptation were 0.88 and 0.12 respectively. The optimal reliability-based calibration theory posits that adaptation is the largest in the least precise modality (Ghahramani et al., 1997). To determine whether these effects where consistent with this theory, the variances of pre-exposure localization for vision and proprioception were computed. The former (336 mm²) was significantly larger than the latter (54 mm²; $p<0.0001$). On average, the relative adaptation for vision (0.88) approximated the inverse of its relative reliability (0.81; $p = 0.4$). Overall, these results are consistent with the hypothesis that information from vision and proprioception is calibrated optimally to minimize estimated-position uncertainty (van Beers et al., 2002). Recent studies also suggest an influence of distorted visual feedback on visual reliability (van Beers et al., 2011). The neural correlates of in-depth coding for action and the corresponding visual and proprioceptive integration have been recently investigated, emphasizing the role of the posterior parietal cortex (Ferraina et al. 2009).

36.455 **The effects of adaptation on visual search.**

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Temporal context or adaptation, the preceding seconds to minutes of stimulus history, profoundly affects visual perception. Despite the robustness and ubiquity of these effects, their functional role in perception and cortical processing in many cases remains unclear. In contrast, the effects of spatial context and their role in perception are better understood: spatial contextual effects highlight features that differ from those in surrounding regions, determining salience and giving rise to 'pop-out'. Similarities in the perceptual and neural effects of spatial and temporal context raise the possibility that they may serve similar functions. We therefore tested the possibility that adaptation serves to enhance the salience of features differing from their temporal context. We measured the effects of prolonged (40 s) adaptation to a counterphase grating on performance in a classical search task. Subjects searched for a target whose orientation was offset by 10 - 90° relative to distracters. Distracters were oriented either parallel or orthogonal to the adapter. We find that adaptation reduces both reaction times and the number of saccades made to find targets with small orientation offsets, suggesting that adaptation can enhance the salience of such targets. By extending existing models of salience to include the effects of adaptation, we illustrate how stimulus-specific adaptation and center-surround antagonism in early visual pathways could give rise to such effects. Our results provide evidence of a beneficial effect of adaptation on perception, and suggest a new view of the role of adaptation in perception and cortical processing.

36.456 **Behavioral and fMRI Measures of "Visual" Processing with a Sensory Substitution Device**

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Background Worldwide 45 million people are blind. Sensory substitution may restore visual function by encoding visual information into a signal perceived by another still-functional sensory modality, such as audition. The vOICe device, for example, captures a video image and encodes vertical position as distinct frequencies, horizontal position as scan time (left-to-right), and the brightness of individual pixels as volume (Amedi, 2007) Method Behavioral tests were devised to monitor vision-like processing development during training on the vOICe device. Sighted subjects performed "visual" tasks while wearing glasses with small-embedded camera, attached earphones, and a connected portable computer. fMRI was performed in a 3 Tesla magnet with pre-recorded vOICe signals. Results During the localization task, a white circle is placed in one of five locations on a black felt covered board and the subject points to the object's center. During a training period of 4.5-6 hours four sighted subjects improved their reach inaccuracy from an average of 6.79 inches to an average of 3.85 inches. A forced-choice recognition task of 4-5 office objects showed an accuracy (average 95 %), which was well-above chance (average 21.25 %). A study of mapping visual space to visual activation (via vOICe encoding) using fMRI has also been performed. Preliminary results (N=1) show bilateral activation of V3 (BA 19) when a visual dot in the left visual field is encoded in vOICe and localized by the subject and left V3 activation when the dot is on the right. Discussion Behavioral results indicate that visual processing skills can be acquired with vOICe device use. The (prelim.) fMRI results were also consistent in that the vOICe localization training develops vision-style sensory processing from the auditory inputs.

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36.457 **Improving Reading Speed in Peripheral Vision with Perceptual Learning: A Behavioral and fMRI Investigation**

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Practicing a perceptual task often leads to improved performance, termed perceptual learning. The improvement is often specific to the task and trained retinal location. Here, we report on a project using psychophysics and fMRI to address two questions: Is perceptual learning in eccentric reading transferable to an untrained retinal locus or a task non-related to reading? Are there training-related changes in the functional responses in retinotopic or non-retinotopic areas of visual cortex? Four young normally sighted subjects were trained (1hour/day over 4days) to read sentences displayed in the lower visual field (10º eccentricity) using the Rapid Serial Visual Presentation (RSVP) paradigm. Pre- and post-training psychophysical tests included RSVP reading speed, visual span and orientation discrimination (Gabor patch) measurements in both the trained (lower) and untrained (upper) visual fields. Functional MRI measurements (BOLD) were recorded before and after training for: eccentric RSVP reading and grating orientation discrimination. The fMRI measurements used a rapid event-related design, with analysis focusing on multiple regions of visual cortex, including primary visual cortex (V1) and visual word form area (VWFA). Post-training measurements showed a significant gain in RSVP reading speed of 60% (±25%) in the trained visual field. This improvement partially transferred to the untrained location. Orientation discrimination thresholds were not significantly different after training. Preliminary data analysis showed that, following training, there was enhanced BOLD signal in the VWFA for the fastest presentation rate for both the trained and untrained locations, but not in the early visual cortex. Our behavioral data confirm the existence of perceptual training effects in eccentric reading with normal subjects. The training partially transferred to an untrained retinal location, but did not transfer to a task (orientation discrimination) unrelated to reading or letter recognition. Further exploration of our fMRI data may reveal additional cortical site(s) of this form of perceptual learning.

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36.458 **The "pull" in the push-pull perceptual learning protocol to reduce sensory eye dominance underscores the role of interocular inhibition**

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Sensory eye dominance (SED) is reduced with a push-pull perceptual learning protocol that uses exogeneous attention cueing in a binocular rivalry stimulation to force the weak eye to dominance (Ooi & He, 1999; Xu et al, 2010). A major factor triggering learning is the suppression of the strong eye (pull) as the weak eye is excited (push), rather than the attention cueing of the weak eye in itself. To support this contention, we designed two new push-pull protocols without attention cueing. Instead, we manipulated the boundary contour (BC) strength of the rivaling half-images. In the first, BC-1 push-pull protocol, an image with grating feature but no BC was presented to the strong eye. In the second, BC-2 push-pull protocol, an image with grating feature and BC was presented to the strong eye. The weak eye in both protocols received an image with very strong grating feature and BC to ensure its dominance. Each observer underwent both protocols at two parafoveal locations. We found that similar to the original push-pull protocol with attention cueing, both BC-1 and BC-2 push-pull protocols significantly reduce SED and improve stereopsis. This indicates that perceptual learning is triggered as long as the strong eye's image is suppressed, whether by exogeneous attention cueing of the weak eye or by increasing the stimulus strength of the weak eye. Our data also reveal that the perceptual learning effect is larger in the BC-2 push-pull protocol where the strong eye's image carried both grating feature and BC information. Thus, compared to the strong eye's image in the BC-1 push-pull protocol that only had grating feature, this suggests that learning is more effective when there are more image attributes to suppress. Overall, this study further underscores the significance of the "pull" component in the push-pull learning protocol to effectively reduce SED.

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36.459 **Opposite Training Effect in the Ventral Pathway for Tactile Face Perception in Congenital and Late-Onset Blindness**

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INTRODUCTION: It is well known that face perception is mediated in the ventral visual pathway. Although face activation in this part of cortex has been reported in late blind (LB), contradictory results have been found in congenital blind (CB) subjects. Here we directly compared CB and LB subjects and asked whether training on tactile face perception would produce the same or different effects in the ventral pathway of the two groups. METHODS: We used a non-visual drawing-based training paradigm (Likova 2010) to train and study groups of CB and LB subjects. Each subject was required to explore a set of raised-line tactile face profiles with left hand. These profiles were different from each other in appearance and expression. A five-day one-hour training was applied to learn to recognize and reproduce the fine facial characteristics. FMRI (Siemens 3T scanner) was run before and after the training. The group activation maps for the two groups were generated and shown on a single brain. Bilateral regions of interest (ROI) - LOC, FFA, and OFA, were defined. RESULTS AND CONCLUSIONS: Differential activation was found across the two hemispheres. In the left hemisphere, before training the CB-group showed minimal activation in all three ROIs in contrast to strong activation after training, while the LB-group showed the opposite effect of strong activation before training in contrast to reduced activation after training. In the right hemisphere, the training effect was minimal, although generally in the same direction, with the exception of LOC, which hardly showed any significant change in both groups. These results are of importance for better understanding of brain plasticity and rehabilitation strategies in two types of blindness.

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36.460 **Visual influences on selective adaptation in speech perception**

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Previous research testing audiovisual speech stimuli (videos of faces uttering syllables) suggests that selective adaptation in speech perception is purely auditory in nature (Roberts & Summerfield, 1981; Saldaña & Rosenblum, 1994; but see Bertelson, Vroomen, & de Gelder, 2003). However, this research tested whether audio, visual, or audiovisual adapters influence perception of only auditory phonemes which vary over a continuum. In the current experiment, we tested adapter influences on audiovisual stimuli which vary over a visual continuum. This test continuum consisted of nine audio-/ba/-visual-/va/ McGurk-effect stimuli (e.g. McGurk & MacDonald, 1976) ranging in clarity of visual information. The continuum was created by placing a Gaussian blur at a radius of 6, 9, 12, 15, 18, 21, 24, 27, and 30 pixels over the mouth of a speaker articulating /va/. Prior to any adapter exposure, participants consistently perceived tokens from this visual continuum, dubbed with audio /ba/, as /va/ at radii of 6 to 9 pixels and as /ba/ at radii of 27 to 30 pixels, with middle-clarity stimuli perceived sometimes as /va/ and sometimes as /ba/. Participants first exposed to a clear audio-/ba/-visual-/va/ adapter perceived more continuum stimuli as /ba/, $F(1,10)=8.219$, $p<.05$, $\eta 2=.451$. Participants also perceived more continuum stimuli as /ba/ following exposure to an audio-/va/-visual-/va/ adapter, $F(1,8)=18.232$, $p<.01$, $\eta 2=.695$, and a visual-alone /va/ adapter, $F(1,9)=11.704$, $p<.01$, $\eta 2=.565$. These results suggest that visual information can be selectively adapted in audiovisual speech perception. However, participants exposed to an audio-alone /va/ adapter did not exhibit this influence, $F(1,9)=.484$, $p=.504$, $\eta 2=.051$, and there was no difference in the strength of the audio-/va/-visual-/va/ adapter and the visual-alone /va/ adapter, MD=.019, $p=.800$. Overall, the results suggests that, at least for blurred mouth stimuli, visual speech perception is susceptible to selective adaptation to salient visual information, but not to auditory, or cross-modal information.

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Visual memory: Capacity and resolution II

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

36.501 **Working memory is integral to visual search**

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Multiple models suggest that working memory (WM) provides the online workspace for apprehending items during visual search. In line with this hypothesis, we found that WM capacity strongly predicts search efficiency. Previous work, however, has found that search remains efficient when observers are given a concurrent memory load during search (Woodman et al. 2001). Although this finding suggests that working memory is not needed for apprehending search items, our hypothesis is that subjects may have dropped the stored items from WM in anticipation of the search phase of the dual task. In this case, observers could have relied on retrieval from recently activated long term memory to respond to the memory probe at the end of the trial. To test this hypothesis, we measured storage-related neural activity (contralateral delay activity; CDA) while subjects performed a WM/search dual task in which the memoranda occupied one visual field and the intervening search array was presented in the other. If search and WM are independent processes then the storage-related CDA should be equivalent in the single and dual task conditions. Conversely, if subjects drop the memory items in anticipation of the search array, then CDA amplitude contralateral to the memoranda should drop in the dual task condition. The behavioral results replicated the strong correlation between WM capacity and search efficiency. Second, CDA amplitude in the dual task condition dropped during the interval between memory encoding and search onset. Finally, the size of this drop in storage-related neural activity predicted behavioral costs in both memory and search during dual task relative to single task conditions. These data suggest that visual search and WM storage rely on a common resource, but that observers minimized dual task costs by offloading items from WM when search was required. Thus, visual working memory is integral to visual search.

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36.502 **Does displaying visual information in depth improve iconic memory**?

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We obtained cued partial reports of arrays of 9 letters, 3 per row, to trace out iconic decay (Sperling, 1960). Letters were enlarged in successively lower rows below fixation to form a size gradient with more eccentric letters being larger. In 'flat', disparity was adjusted to cancel the depth impression caused by the size gradient. In 'depth', disparity reinforced the size gradient, so that the larger (bottom) letters appeared closer to the observer and the smaller (top) ones further away, as on an inclined plane. One row was cued at random in each display with an arrow. Letter and cue displays were 50 ms in duration. ISIs were -100 (cue before), 100, 300, or 700 ms (cue after). Results: reports were less accurate in 'depth' than in 'flat', at all ISI's. We speculate that shifting attention across depth planes is slower than shifting within a depth plane, so more letters are lost in 'depth' than in 'flat' before transfer to working memory for report. In contrast, when the relevant depth plane is known in advance, so an attention shift is not required, Xu & Nakayama (JoV, 2009) found that depth improves visual memory by 5%.

36.503 **Effect Of Distractors On Encoding And Memorization Of Direction-of-motion Information During Tracking**

Haluk Ogmen[1,2](ogmen@uh.edu), Onur Ekiz[1], Srimant Tripathy[3], Harold Bedell[2,4]; [1]Dept. of Electrical & Computer Engineering, University of Houston, [2]Center for Neuro-Engineering & Cognitive Science, University of Houston, [3]Bradford School of Optometry & Vision Science, University of Bradford, [4]College of Optometry, University of Houston

Purpose: Recently, we have shown that direction-of-motion information is stored into high-capacity transient ("sensory") and low-capacity sustained (Visual Short-Term Memory, VSTM) memory systems by use of graded resources (Shooner et al., 2010). Vision is purposeful in that we selectively attend to a subset of stimuli (targets) while ignoring the rest (distractors). Here we investigated how distractors influence the encoding and memorization of direction-of-motion information. Methods: Observers (N=4) viewed one to sixteen 1-deg circular disks in random linear motion (duration=200ms). A subset of the disks (1–9) was tagged as "targets" at the beginning of each trial. The remaining disks were distractors. At the end of the trial, observers reported the perceived direction-of-motion of a cued target. We measured performance as a function of target and distractor set-sizes and cue-delay, and we assessed the performance of four statistical models (Gaussian, Gaussian+guessing, and two versions of Gau ssian+guessing+confusion/misbinding). The parameters of the best fitting model (Gaussian+guessing) were used to assess the accuracy, precision, capacity, and dynamics of visual encoding and memory. Results: Encoding and memorization of direction-of-motion information remain accurate over a broad range of target and distractor set-sizes. An increase in target set-size causes a linear decay in performance, indicating a limited capacity for encoding and memorization. Distractor set-size influences only sensory memory; it has no effect on the encoding and VSTM stages. Sensory memory exhibits a rapid exponential decay. The precision of encoding and memory both decline gradually as a function of target set-size. For memory, this decline exhibits a lower bound of ~0.03–0.05deg-1. Conclusions: Our results support an atomic model of resource allocation in which resources are shared until a minimum usable resource level is reached. The resources are vulnerable to distractors only during the transient period when information is transferred from the encoding stage to VSTM.

36.504 **Structured representations in visual working memory: Using results from individual displays to constrain cognitive theory**

Timothy Brady[1](tbrady@wjh.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

Influential models of visual working memory assume we encode items independently and examine how many individual items can be remembered. However, observers remember not only individual items but also ensemble statistics, like mean size or color.Here we show that these levels of representation are not independent, even when observers remember displays of random colors. Exp. 1:Observers remembered several colored dots, and after a delay, reported the color of a dot selected at random. We estimated the rate of random guessing, and whether it depends on how items are clustered in color space. At set size 3, even subtle differences in clustering resulted in different guess rates: with distractors 90 and 180° in color space from the tested item, the guess rate was 24%; at 60/120°, the guess rate was only 13% ($p<0.05$). In fact, with distractors somewhat clustered, observers rarely guess even at set size 5 (distractors: 30/60/90/120°; guesses: 7%). These clustering effects suggest that observers make use of the ensemble statistics to know something about all of the items. Importantly, clustering in color space is inherently more likely at low set sizes, and thus guess rates at low set sizes are systematically underestimated in all experiments using these methods (up to 30%). Exp. 2:In a second experiment, we tested hundreds of observers on the same displays (N=465 on each), and found that models that do not take into account the relationship between items fail to fit the data on any particular display, even though they fit on average across all displays. Models that take into account how clustered in hue the items are (e.g., ensembles) are required. We suggest that observers' use of ensembles, which vary from display-to-display, make studying capacity by averaging across displays impossible, and requires a new framework based on large amounts of data on individual displays.

36.505 **Measuring the Coefficient of Variation with continuously varying arrays**

Ryan Ly[1](rly@princeton.edu), Hee Yeon Im[2], Robert Eisinger[2], Justin Halberda[2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Psychological and Brain Sciences, Johns Hopkins University

Representation of visual features is subject to internal noise, which is sometimes constant (e.g., color), anisotropic (e.g., orientation) or scalar (e.g., luminance) within a dimension. A common metric of internal noise has been the coefficient of variation (CV=SD/mean), which is equivalent to a Weber fraction. For many features, SD varies linearly with the mean such that larger values are subject to higher internal noise (e.g., luminance, number, filled region, length). In such cases, a traditional approach to estimating CV has required testing an observer on a subset of values across many trials in order to generate sufficient data for determining both SD and mean of estimates. Here we describe an analytic transformation of response data which allows the accurate estimation of CV given sparse and distributed observations. We validate this new approach with data from three paradigms. In Experiment 1, observers were asked to shout out how many yellow dots were presented in a visual array consisting of multiple yellow and blue dots. In Experiment 2, observers were given a number and asked to make key-presses to arrive at the approximate number of presses. In Experiment 3, observers clicked to approximately locate a given number on a continuous number scale labeled with the endpoints 0 and 100. Throughout the 3 experiments, our new method yields stable estimates of CV that correlate with those from the traditional method and generate accurate fits with far fewer observations and no repetitions of particular values. Our alternative approach can be particularly powerful given brief assessments. It allows a less biased estimate of CV because our sparse sampling of many values disables brittle response strategies that arise during the traditional repeated testing. This approach can be applied quite broadly to psychophysical assessments of internal noise and/or estimates of the resolution of visual representations.

36.506 **Integrated Model of Visual Working Memory**

Wilson Chu[1](wchu3@uci.edu), Barbara Dosher[1], Zhong-Lin Lu[2,3]; [1]Department of Cognitive Sciences, University of California, Irvine, CA, [2]Department of Psychology, The Ohio State University, Columbus, OH, [3]Department of Psychology, University of Southern California, Los Angeles,

Models of visual working memory (VWM) have recently been assessed using cued feature report, predicting performance for clearly visible stimuli by estimating the probability of being in VWM and the variability of feature encoding (Zhang & Luck, 2008; Bays, et al., 2009). However, VWM presumably must operate on low contrast and noisy stimuli, not just on highly visible ones. We report an integrated multi-alternative template model of VWM with stimulus variations of contrast and external noise that provide demanding new tests. 900 ms after display, the observers were cued to report the orientation of one of up to four briefly presented Gabors from a selection of 20 orientations (every 9°). We measured display size effects (1, 2, 4) with and without external noise for Gabors at eight contrast levels. Memory report was systematically affected by display size, Gabor contrast, and external noise, varying from poor to excellent. Yet, there is a surprising similarity of the spread of the reports around the correct orientation for conditions at many levels of performance. A multi-alternative perceptual template model provides a full account of the data. Twenty templates respond with gains depending on the match between each template and the cued target stimulus. Additive and multiplicative noises are added to the outputs of the templates. A max rule chooses the response. Focal attention in smaller displays enhances the representations by reducing internal additive noise and improved filtering of external noise, so estimates of total internal noise increase with display size (Wilken & Ma, 2004). However, the spread of the distribution of the reported orientations does not vary with display size – it is determined by the tuning of the competing templates.

Sunday PM

The multi-alternative template model provides a parameter-efficient and counter-intuitive integrated account of VWM and attention over many display conditions, challenging existing VWM model.

Acknowledgement: National Institute of Mental Health Grant # R01MH81018

36.507 **The Cost of Manipulating Representations in Visual Working Memory**

Hrag Pailian[1](hrag.pailian@gmail.com), Justin Halberda[1]; [1]Psychological and Brain Sciences, The Johns Hopkins University

Visual Working Memory (VWM) representations might require active maintenance, but research has focused predominantly on storage as opposed to the updating and manipulation of these representations. For example, VWM might maintain three unique features bound to three unique positions with little or no cost (Luck & Vogel, 1997; but see Bays & Husain, 2008), but it remains relatively unknown how these VWM representations may or may not suffer under conditions of manipulating and updating. Here, we investigated the costs of manipulation in VWM using a variant of a shell game. Participants were presented with a memory display consisting of 2, 3, or 4 colored circles. These colors then disappeared leaving only uniform outlines of these objects. Pairs of objects then underwent smooth motion and switched positions. The number of switches varied from 0 (static) to 4. After switches, one object was filled and subjects judged whether it was the expected or an unexpected color. Results suggest that there is little or no cost to updating color information for 2 stored representations. However, while participants were accurate at maintaining 3 and 4 individual static colors (consistent with classic results, e.g., Luck & Vogel, 1997), they showed significant cost when updating of these color-position bindings was required. Consistent with some previous tests of updating in non-visual memory domains (e.g., counters, Garavan, 1998; Feigenson & Yamaguchi, 2009), our experiments reveal somewhat independent limits for the storage of static information and the active manipulation of information in VWM.

Acknowledgement: Natural Sciences and Engineering Council of Canada

36.508 **Both Precision and Capacity of Visual Working Memory Are Impaired by Face Inversion**

Elizabeth Counterman[1](e.counterman@gmail.com), Frank Tong[1]; [1]Department of Psychology, Vanderbilt University

The ability to actively maintain recently viewed visual information is essential to many aspects of daily life, and working memory for faces is of particular importance for human social interactions. Recent studies have found that working memory performance is better for upright faces than inverted faces, but it remains unclear whether this advantage for upright faces is attributable to superior memory capacity for these highly familiar stimuli (Curby & Gauthier, 2007) or to the superior precision with which these items can be retained (Scolari, Vogel, & Awh, 2008). Here, we investigated whether upright faces are retained in working memory with superior precision or capacity by assessing participants' reported memories of such stimuli, using a continuously varying set of computer-generated faces. Observers viewed 1-5 sequentially presented faces for 1.5s each, then after a 3s retention interval, a spatial cue indicated which face to report from memory via method of adjustment. Faces were presented upside-down on alternating blocks of trials. We analyzed the distribution of errors using a mixed model approach to separately estimate the precision of memory for successfully retained faces and the frequency of random guess responses (Zhang and Luck, 2008). Pooled results from 16 participants indicated that specialized processing of upright faces conferred an advantage to both working memory capacity and resolution. Estimated capacities for upright faces were greater than for inverted faces (~3.5 vs. 2.5, respectively), and the precision of working memory also proved superior in the upright condition. Taken together, our results suggest that upright faces can be represented more efficiently in working memory, allowing for greater capacity, while at the same time these upright faces can be maintained with greater visual precision.

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36.509 **It's not easy to forget**

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We are studying familiarity memory (knowing that I have seen this image somewhere. sometime before) and identification memory (knowing where and when I saw it, and perhaps its name). We now address memory decay in these conditions, including cases when forgetting is desirable. We introduce a multiple-item memory task, where subjects report repetition of any stimulus in a sequence. Two primate groups participated: Group TB (n=2) trained with a fixed set of 16 images, with many between-trial image repetitions. Group DL (n=2) were trained with an unlimited number of novel images, except for some "catch" trials with previously-seen images. Performance reflects two types of error: Misses, not reporting a repetition, and False Positives (FP), erroneously responding to an image which is not a within-trial repetition. FPs often occur for images which were present in a previous trial - as occurs frequently with the fixed set. Still, group TB had few FPs, and they drop off quickly with number of trials since the original presentation (mean: 1-trial-back: 9%; 2-trials-back: 3%). We suggest presence of an inter-trial reset mechanism which "forgets" (most) seen images. With unlimited novel images, however, group DL had many FPs (1-trial-back: 80%; 2-trials-back: 66%), suggesting they used familiarity memory. Group DL did not experience inter-trial repetitions during training, so perhaps they didn't develop the inter-trial reset. When the tasks were switched, group TB utilized its previously-learned reset also for novel images, and group DL now established reset. Furthermore, group DL, originally without reset, afforded a unique opportunity to estimate memory decay without reset. Memory gradually decreases, with ~20% forgotten each trial (~5s), so that ~10% of images remain in memory and produce FP errors following 10 trials. We conclude that primates easily remember dozens of images, with a fixed gradual loss of image recognition over many minutes.

Acknowledgement: Israel Science Foundation

36.510 **Is visual working memory capacity driven by mental imagery strength?**

Joel Pearson[1](jpearson@unsw.edu.au), Rebecca Keogh[1]; [1]School of Psychology, The University of New South Wales

Visual working memory provides an essential link between past and future events. Here we measured visual working memory using a two alternative forced choice paradigm. To assess capacity observers were required to remember the orientation of each element in a circular array of different set sizes, composed of small Gabor patterns. We then assessed the strength of mental imagery in each observer using the previously documented binocular rivalry technique. Individuals with strong visual mental imagery had a greater visual working memory capacity than those with intermediate or poor imagery. However, mental imagery strength did not predict the capacity limits in a number working memory task. In addition, increasing the background luminance during the retention interval reduced the visual working memory capacity (of good imagers), but not their number working memory capacity. Likewise, increased background luminance during imagery generation attenuated the effects of mental imagery on subsequent perception (only for good imagers). This suggests that luminance signals were disrupting visual sensory-based mechanisms and not a general working memory system. These results suggest that visual working memory, but not number working memory capacity is closely related to an individual's imagery strength. We hope these findings might help reconcile current controversy regarding the mechanism and neural location of visual mnemonic storage.

36.511 **The effect of retrocues depends on the response mode: the influence of visual pathways**

Michael D. Patterson[1](mdpatterson@ntu.edu.sg), Shanshan Yang[1]; [1]Division of Psychology, College of Humanities, Arts, and Social Sciences, Nanyang Technological University

Visual processing has often been broken into two main pathways: one for identification of visual objects, and one for interaction with visual objects (Mishkin and Ungerleider, 1982; Goodale and Milner, 1992). Two experiments compared the effects of retrocues on different response modes which may recruit processing from different visual pathways. Each stimulus consisted of 6 colored dots placed randomly in the center of a computer screen for 1.5 seconds. An auditory retrocue for the color of one dot was presented either simultaneously with the visual stimulus, immediately after the stimulus vanished, or 2 seconds later. In some trials, the auditory cue was non-informative and served as a control condition. Approximately 4 seconds after the visual stimulus was presented, participants were shown five of the original dots and asked to indicate where the missing dot was. In experi-

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ment 1, to identify the location, participants were instructed to enter the x and y axes' labels that indicated the location of the missing dot on a grid. In experiment 2, an interaction experiment, participants were asked to move the mouse to place the cursor at the location of the missing dot. Compared to the control condition, retrocues only improved accuracy in the identification response mode experiment, but not in the interaction experiment. The results cannot be due solely to movement interfering with the spatial memory representation since the accuracy in experiment 2 was higher than that in experiment 1. These results corroborate previous experiments, in which color retrocues improved accuracy on a shape change detection task when the retrocues indicated which part of the shape would change (Patterson & Neo, 2008). Thus, these results suggest humans may be limited in their ability to flexibly alter attention within memory depending on the type of response and which visual pathways are recruited.

36.512 Memory For Directions Of Motion Of Multiple Objects Undergoing Bilinear Motion

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Purpose: When several objects move along linear trajectories, information regarding their direction-of-motion is stored into high-capacity transient ("sensory") and low-capacity sustained (Visual Short-Term Memory, VSTM) memory systems by use of graded resources (Shooner et al., JOV, 2010). We now extend our earlier study to objects moving along bilinear trajectories, i.e. trajectories with a large deviation halfway through the trial. This task involves monitoring current as well as previous states of the objects. Methods: Observers attentively tracked multiple objects (n = 1 to 4) with bilinear motion trajectories and were cued to report one (Partial-Report, PR) or all (Full-Report, FR) directions of motion, either before deviation or after deviation. Experimental conditions (PR_before-deviation, PR_after-deviation, FR_before-deviation, FR_after-deviation) were randomly interleaved in each block. We measured precision as a function of stimulus duration (Exp1; t = 200-1200ms, n=3), set-size (Exp2; t = 800ms, n = 1 to 4) and the cue-delay (Exp3; t = 800ms, n = 3, delay = 0-1200ms; the delay was applied to after-deviation trials only). Results: Precision was greater for after-deviation conditions than for before-deviation conditions, consistent with the longer duration of decay of sensory memory for the latter. In Exp1, precision improved with duration and saturated around 800ms in all four conditions. Exp2 showed steeper loss of precision for FR compared to PR and for before-deviation compared to after-deviation. In Exp3, the precision in the after-deviation condition did not decay to the precision in the before-deviation condition, even when the cue in the after-deviation condition was delayed by 1200ms. Conclusions: Our results suggest that decay of sensory memory partially accounts for the loss of precision during tracking deviations in trajectories (Tripathy & Barrett, JOV, 2004). In addition, the performance in the before-deviation conditions cannot be explained by any model of tracking that only monitors the current state of tracked objects.

Visual search

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

36.513 Visual search at the airport: Testing TSA officers

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A significant challenge for laboratory-based research is to adequately replicate conditions found in the real world. Likewise, a challenge for field-based research is to appropriately maintain the precision and control found within the laboratory. These hurdles are easily noticed when studying visual search, the act of finding a target amongst distractors. Decades of laboratory-based research have revealed many factors affecting visual search (see Nakayama & Martini, 2011 for a recent review); yet, these 'sterile' tasks conducted with novice participants can at times bear little resemblance to the tasks of professional searchers such as baggage screeners, radiologists, lifeguards, and military personnel. Conversely, conducting research with expert searchers in their natural environment can be logistically complex, which limits the scope of questions that can be asked. We are bridging this gap by conducting laboratory-based research with professional, expert searchers: employed Transportation Security Administration (TSA) officers at Raleigh-Durham International Airport. We have established a cognitive psychology laboratory within the airport, and the TSA officers participate in our research studies during their normal work hours. We are assessing a variety of visual and attentional abilities, including several measures of visual search. For example, in one task we employed a simplified visual search experiment to directly compare novice searchers (Duke University undergraduates) to expert searchers (TSA officers). Participants looked for 'T's amongst 'L's with set sizes of 8, 16, 24, and 32. Compared to undergraduates, TSA officers were slower to respond, with search slopes approximately 1.5 times larger. Importantly, the TSA agents were also more accurate at each set size, suggesting a greater search diligence. Through tasks such as these, combined with measures of individual differences (e.g., personality and clinical assessments), the goal of this project is to inform both cognitive theories of visual search and the TSA's standard operating procedures.

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36.514 Finding what is new in hybrid visual and memory search: a new search asymmetry.

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In many visual search tasks, we search for any of several targets (Are any of the members of my English class here in the school cafeteria?). Such tasks are "hybrid" visual and memory searches. Wolfe (2012) found that RTs in hybrid tasks increase linearly with the visual set size but logarithmically with the memory set size. Using photos of objects, this logarithmic relationship was demonstrated for memory set sizes up to 100. In those experiments, observers search for the item that was in the memory set. What would happen if observers searched for the item that was not in the memory set? In classic visual search, the absence of a feature is often harder to find than its presence. Would such an asymmetry be seen in hybrid search? We asked observers to locate the one new item in a visual display that contained 6 or 12 displayed items, as distractors. Obviously, an item can only be new once. Thus, once observers found the new item, they were told to remember it; meaning that the memory set size increased by one on each trial. 12 observers were tested for 600 trials. Unsurprisingly, error rates rise as the memory set size rises but only to 12% for memory sets of 500-600 items. RT remains a linear function of log(memory set). Moreover, the slopes of the memory set functions in this experiment closely match those of the previous hybrid search experiment. However, the mean RTs are significantly slower than predicted from prior experiments. This suggests that it takes longer to make a decision that an item is the new target among old distractors than it does to decide that this is the old target among new distractors. In hybrid search, novelty does not pop-out.

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36.515 A search model for imperfectly detected targets

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Under the assumptions that 1) the search region can be divided up into N non-overlapping sub-regions that are searched sequentially, 2) the probability of detection is unity if a sub-region is selected, and 3) no information is available to guide the search, there are two extreme case models. The search can be done perfectly, leading to a uniform distribution over the number of searches required, or the search can be done with no memory, leading to a geometric distribution for the number of searches required with a success probability of 1/N. If the probability of detection P is less than unity, but the search is done otherwise perfectly, the searcher will have to search the N regions repeatedly until detection occurs. The number of searches is thus the sum two random variables. One is N times the number of full searches (a geometric distribution with success probability P) and the other is the uniform distribution over the integers 1 to N. The first three moments of this distribution were computed, giving the mean, standard deviation, and the kurtosis of the distribution as a function of the two parameters. The model was fit to the data presented last year (Ahumada, Billington, & Kaiwi, 2011 VSS) for the number of fixations required to find a single pixel target on a simulated horizon. The model gave a good fit to the three moments for all three observers.

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36.516 How visual set statistics adjust an 'attentional window': An information theory of visual search

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Experiments of the last decade showed that preattentive system can construct statistical representations of sets (Ariely, 2001) and subsets (Chong & Treisman, 2005a) of objects. To compute statistics visual system should evaluate instances of objects and probabilities of their occurrence in a set. The knowledge of instances and probabilities appears sufficient to compute information entropy of a set, as proposed by Shannon (1948). The theory proposed here suggests that preattentively computed statistics can adjust attentional window in visual search through entropy calculation. This brings new insights into classical visual search phenomena. For example, entropy calculation revealed that attentional capacity of a feature visual display should be just a bit smaller (for sets of under 16 items) or even larger (sets of over 16 items) than a real set size. This implies near parallel mode of attentional processing that fits 'pop-out' pattern of feature search. For conjunction displays, entropy calculation revealed rather constant capacity of 1-1.3 items at once irrespectively of set sizes that corresponds to serial search. Another explained phenomenon is attentional capture by a singleton (Theeuwes, 1991). The entropy of a singleton set is larger than the of one without a singleton and this implies narrower attentional window yielding slower target detection. Finally, the theory suggests an account of similarity effects on visual search (Duncan & Humphreys, 1989). If preattentive vision tends to average similar objects under one distribution and separate dissimilar objects into distinct distributions (Chong & Treisman, 2005b) then entropy of a dissimilar set should be larger than of a highly similar set. Hence, attentional window is wider when dissimilar target is to be detected among similar distractors. When similar target is among similar distractors they tend to be averaged under the same distribution. Here, entropy is near zero, preattentive control of attentional window fails and top-down control is predominantly involved.

Acknowledgement: The Programme of fundamental research of HSE

36.517 A unilateral field advantage in visual search and detection

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Superior visual processing of information distributed across hemifields than in a single hemifield (bilateral field advantage) has been reported in tasks that require parallel processing (e.g. Sereno & Kosslyn, 1991). This study comprises a series of experiments exploring hemifield effects in visual search and detection. Experiment 1 explored the hemifield effect on dual-target search, in which subjects searched for two designated targets ("T" in two different orientations) among distractors (rotated "L"s). On each trial, subjects saw a crowded display (180 msec) of twenty items (see Figure 1) and reported the presence of each of the two targets. When both present, the two targets appeared in the same hemifield (unilateral) or in opposite hemifields (bilateral). Subjects were more likely to detect two targets simultaneously on unilateral trials, suggesting a unilateral field advantage (UFA) in searching for two targets. Experiment 2 examined if the UFA in Experiment 1 was due to the task demand of detecting two targets. Subjects performed a detection task in Experiment 2A, in which they reported the number of targets (rotated "T"s) present (0, 1 or 2), and performed an identification task in Experiment 2B, in which they identified the orientations of targets (rotated "T"s). In both tasks (see Figure 2, 3), each trial contained six items, spreading within a single hemifield (unilateral) or across hemifields (bilateral). UFA was found in detection but not in identification, and was evident only in detecting two targets. Experiment 3 replicated the findings in 2A's detection task with 3D shaded cubes. The results suggest that UFA depends on the task demand of detecting multiple targets simultaneously. We demonstrated a UFA in visual search and detection of more than one target. We argue that this UFA is likely due to greater integration of target signal within the same hemifield than across hemifields.

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36.518 Modeling Inefficiencies in Visual Search

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We have previously shown that visual search performance is well predicted by peripheral discriminability between patches containing multiple distractors and those containing distractors plus a target (Rosenholtz et al, in submission), which in turn is well predicted by a model in which the representation in peripheral vision consists of a rich set of summary statistics (Rosenholtz et al, in submission, and VSS 2009). Furthermore, we have developed an Ideal Saccadic Targeter model (saccades are made to the most likely target given the observations) to quantitatively predict mean number of fixations to find a target (Rosenholtz et al, VSS 2010). In this study, we examine four possible sources of inefficiency in human searchers relative to the ideal observer. (1) Memory. We compared the performance of the model with memory of the past k fixations against that of a memoryless model. (2) Location Uncertainty. We introduced location uncertainty by removing direct information about item location, so the model has to infer possible target locations from observations. The model has found the target if it fixates within one degree of it. (3) Saccade Length. Because humans prefer to saccade smaller distances (Zelinsky, 2008), we tested three ways of imposing this inefficiency: (a) strictly limiting saccade length, (b) having the model make intermediate saccades to a desired fixation point beyond a saccade limit, and (c) imposing a cost which depends on saccade length. (4) Ideal Decision Rule. We investigated the difference in search efficiency when using the optimal (maximum-a-posteriori) target location as opposed to picking the location with the highest targetness observation. Whether and how much memory was required depended on how saccade limitations were imposed. In general, the interaction between inefficiencies are complex. We show how the model predictions varies with these inefficiencies, and what sets of parameters best match observed human subject performances.

36.519 Detrimental effect of spatial cues predicted by a foveated Maximum a Posteriori eye movement model

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A vast literature has shown that the presence of predictive spatial cues nearly invariably improves performance in a variety of perceptual tasks. However, we previously demonstrated that, for a letter identification search task with predictive spatial cues, human performance was actually hindered by cue presence at high signal contrasts (Mack & Eckstein, VSS 2011). We suggested this could be explained by suboptimal overutilization of cue information. Here, we develop a foveated Maximum a Posteriori (MAP) eye movement model to assess this claim. Task: Humans performed a search task in which they were to indicate which of five letters at one of five contrasts was embedded in a noisy image. In cued sessions, colored cue circles indicated likely target locations with varying probability (80% predictive overall). In the remaining 20% of cued trials, targets appeared outside the circles. In 'uncued' sessions, the statistics of the images were identical (including the probabilistic target location structure) except for the absence of the cue circles. Model: A MAP eye movement model, which weighted visual evidence by the prior probability of target location, was modulated by eccentricity-dependent white internal noise which simulated decreasing visual acuity in the periphery of the human foveated visual system. Internal noise levels were fit to approximate human performance on uncued trials. Results and Conclusions: In model simulations which implemented optimal weighting of visual information, performance for both cued and uncued trials increased with signal contrast, though performance was consistently superior for cued trials. However, for simulations in which visual information at cued locations was suboptimally overweighted, a reversal in performance was seen at high signal contrasts, as uncued performance exceeded cued performance, qualitatively mirroring our behavioral results. Thus, it appears the misuse of even strongly predictive cue information can, in some circumstances, hinder visual search performance.

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36.520 Symbolic distractor cues facilitate search

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When observers practice finding a particular target among a particular type of distractor, their search times become faster. One benefit of practice is that it allows observers to hone a search template that optimally distinguishes the target from the distractors. If observers practice searching for this same target among a different type of distractor, they will likely develop a different search template. This study examined whether observers can switch

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among these search templates if they are provided with a symbolic cue to the distractors' identity prior to the search display. The search items were photographs of four very similar objects (four wristwatches or four fishing lures) with one object selected to serve as the target. In two training sessions, observers practiced finding this target among distractors drawn from the other three objects. Each search display was comprised of the target and five identical distractors arranged randomly but without overlap. Observers indicated whether the target appeared on the right or left side of the display. During the training sessions, displays with different distractors were run in separate blocks of trials, and each trial was preceded by a symbolic cue (a number) that identified the distractors. During a subsequent testing session, displays with different distractors were randomly intermixed, and half of the trials were preceded by the symbolic distractor cue. Ten observers ran the experiment with either the wristwatch or fishing lure stimuli. For all observers, the symbolic distractor cue produced a robust decrease in search times ($t(9) = 5.16$, $p < 0.001$, 15% average decrease) with no change in accuracy. This result indicates that observers can develop multiple search templates for the same target object and that observers can readily switch among these templates to optimize their search.

36.521 **Contextual cues must be visible to be effective**

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When searching for a target in complex visual scenes, reaction time is faster for targets appearing in the repeated contexts than for targets appearing in different contexts (Chun & Jiang, 1998). One example of these contexts is the association between target and distractor shapes (Chun & Jiang, 1999). The current study investigated whether this contextual cueing effect could occur even when some of the stimuli were invisible. We used the same shapes as in Chun & Jiang (1999). One target and eight distractors were always presented in the dominant eye. We made two of the eight distractors invisible using inter-ocular suppression. Specifically, we presented two pattern masks to the corresponding locations of the two suppressed distractors in the opposite eye (invisible condition). This invisible condition was further divided into the two conditions: the two suppressed distractors could be either physically present (masked) or absent (yoked). In addition to this visibility modulation, we had two types of context (consistent or variable mapping between the target and distractor shapes) and six epochs to learn the association between the target and distractor shapes. Participants' task was to search for the single target that was symmetric about the vertical axis. Distractors were symmetric about the differently oriented axes. In the visible condition, we found that improvement in search performance was significantly more pronounced in the consistent contexts than in the variable contexts, as the epoch increased. These results are consistent with Chun & Jiang (1999). However, we did not find this contextual cueing effect both in the masked and yoked conditions. Nevertheless, overall search performance was faster in the masked condition than in the yoked condition. These results suggest that invisible stimuli cannot induce contextual cueing effect. They can only facilitate procedural aspects of visual search.

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36.522 **A neural marker of the representation used to guide visual search**

Joseph Schmidt[1](schmidtjoseph@hotmail.com), Annmarie MacNamara[1], Greg Hajcak[1], Gregory Zelinsky[1]; [1]Department of Psychology, Stony Brook University

Guided search requires a top-down target representation to be maintained in visual working memory (VWM) so that it can be matched to information in peripheral vision. We used contralateral delay activity (CDA; an ERP indictor of VWM load), measured after target designation but before search display onset, to estimate the VWM load generated by the target representation. To investigate the relationship between target representation and later search guidance, we asked whether CDA was more pronounced on trials when the initial saccade during search was directed to the target (strong guidance) compared to when it was not (weak guidance). An arrow cue (200ms) directed attention to either the left or right side of the screen, followed by a 400ms delay, and then the presentation of two photorealistic objects (400ms) on each side of central fixation. This target preview was followed by a 1000ms delay during which CDA was measured, and finally by a four-object search display. One of the cued objects was always present, and observers indicated their localization decision by pressing a button while fixating the target. We found that the expression of CDA across parietal and occipital electrode sites interacted with search guidance ($p \leq .05$). For central-parietal and central-parietal-occipital sites we found our predicted relationship; CDA was larger (more negative) on strong guidance trials compared to weak guidance trials. This would be expected if search guidance improved with the number of target features coded in VWM. However, lateral-parietal sites showed the opposite relationship; significantly larger CDA on poor guidance trials. As well, these sites were negatively correlated with search guidance across observers. We conclude that CDA is a reliable neural marker of the VWM representation used to guide search to visually complex realistic targets. The different expressions of this relationship may indicate that CDA could be useful in revealing the feature weighting processes used to optimize guiding target representations.

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36.523 **Visual Surveillance: The effect of delayed target onset in a change-detection task**

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Many visual tasks require that we monitor scenes that change over time, looking for critical events that can occur (or not) at any time. We use the term visual surveillance to capture these task characteristics. Lifeguarding and driving, for example, are real-world tasks that require visual surveillance. Here we explored the effect of variable target-onset time in visual surveillance using a flickering change-detection task. Observers saw fields of vertical and horizontal bars. The bars were presented for 300 ms, followed by a 200-ms blank screen, followed by bars for 300 ms and another 200-ms blank screen. This sequence cycled continuously for the duration of the trial. The task was to find a single bar that alternated between vertical and horizontal as quickly as possible. There were either 16 or 32 bars in the display (set size), and the change was delayed relative to the onset of the cycling display by 0, 4 or 12 seconds. Change detection times were faster for setsize-16 (5409 ms) than for the setsize-32 (8286 ms). They were also faster in the 4-s (6164 ms) and 12-s (6129 ms) delay conditions than in the 0-s delay condition. There was no reliable difference between the 4- and 12-ms delay conditions, however. The longer delays might have yielded slower performance as observers fatigued with searching the unchanging displays. For at least up to 12 seconds, however, there is no evidence of this. Additional experiments will seek to resolve these ideas.

36.524 **Zooming in and out: Global-local shifts in large scale visual search**

Grayden Solman[1](gsolman@uwaterloo.ca), Daniel Smilek[1]; [1]University of Waterloo

Search outside of the laboratory often involves movement within the search environment, dynamically engaging the visual array in order to bring a particular region of space into view, or to change the size of an object's image in the visual field. In three experiments, we introduce a novel search task in which participants search through displays containing up to 128 items arranged on a search 'canvas' – potentially much larger than the physical display depending on zoom. To search, participants used the mouse scroll wheel to zoom in and out, and a click-drag interface to move the canvas within the display frame at that zoom level. Detection of the unique target item was signaled by clicking on the location of the item. Throughout each trial we recorded the magnification level and position of the frame in order to reconstruct search characteristics in terms of shifts in magnification and shifts in position. Here, we focus in particular on the number of transitions between global (zoomed out) and local (zoomed in) views during search. In Experiment 1, we manipulated item density. In Experiment 2, we replaced the typical homogeneous distribution of items with discrete clumps of items, and manipulated the number of clumps, density of items within clumps, and density of clumps within the entire search field. In Experiment 3, we varied the relative sizes of the items within individual displays, manipulating the number of distinct sizes (1, 2, or 4), and at which level of size the target was presented. We report increased numbers of global-local transitions with decreasing density, with increasing numbers of clumps, and as the number of distinct item sizes in each display increases. These results are consistent with global-local transitions during search being driven by the need to acquire different information from different levels of zoom.

Acknowledgement: NSERC

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36.525 **Collaborative coactivation in search**

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Popular wisdom holds that two heads are better than one, but do two heads engaged in visual search produce a benefit beyond a linear combination of performance from two individuals? We applied Miller's (1982) coactivation model to the analysis of search by pairs of participants. When this model is applied to an individual's search for multiple targets, it predicts that responses to two redundant signals will be faster on average than responses to the faster single signal (i.e., coactivation will exceed the benefits of a race-horse model). Here we examined whether two individuals searching together would produce coactivation, or only horse-race, benefits. We compared individual (n=18) and collaborative (pairs=9) search in a task involving two possible targets at two possible spatial locations. During individual search, each participant was responsible for detecting a target regardless of its identity or location. During collaborative search, each pair was instructed to divide the task by either location ("find either of the two targets, but when they are on your side of the display") or target ("find only one of the two targets, but monitor both sides of the display"). Because visual space can be analyzed by an individual in parallel, whereas multiple targets must be compared serially (Houtkamp & Roelfsema, 2009), we expected to find more evidence for collaborative coactivation in the divided-target condition. The results confirmed our prediction: when pairs of participants divided the search task by location they demonstrated only horse-race benefits, although when they divided by target they exhibited collaborative coactivation. These findings indicate that coactivation models, previously used to understand measurable improvements in individual performance with multiple redundant signals, can be utilized to understand collaborative performance in tasks of joint cognition.

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36.526 **Hide and Seek: The Ultimate Mind Game**

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While a large body of research has focussed on how people visually search for objects, few studies have investigated how people hide objects when given the choice of multiple possible hiding places, an aspect particularly pertinent for security services. We therefore presented an array of items on a touch-sensitive screen and participants indicated under which item they would hide an unspecified target for a 'colleague'. Displays were four by four grids of colored bars which were either homogeneous or included a unique color or orientation item. On each trial, the colleague was identified as either a 'friend' or a 'foe', so that the target was hidden either where it was easy or hard to find. This allowed us to consider two issues. First, whether participants hiding items would be sensitive to the pop-out targets which, as shown by decades of visual search experiments, are most readily selected by people looking for items in the visual field. Second, whether the concepts from embodied cognition might influence the pattern of item choice in the absence of clear visual cues as to where to hide the target. The data suggest both were relevant. When hiding for a friend, more targets were placed behind the unique item or behind items either horizontally or vertically adjacent to this singleton. On homogeneous displays, a selection bias was evident towards items closest to the participant. Targets hidden for a foe, however, were placed away from the singleton, and, in the absence of this unique item, were positioned further from the participant. The corresponding 'find' version, in which participants look for hidden targets, is currently underway. Comparing performance will offer insights in the conceptual differences between hiding and finding, as well as providing an objective and flexible paradigm to test perspective taking and Theory of Mind.

36.527 **Visual search and visual discomfort**

Louise O'Hare[1](lo26@st-andrews.ac.uk), Alasdair Clarke[2], Paul Hibbard[1]; [1]University of St Andrews, [2]University of Edinburgh

Visual discomfort consists of the adverse effects of viewing certain stimuli such as stripes of around 3cycles/degree (Wilkins et al, 1984, Brain, 107, 989-1017), or more generally images whose amplitude spectra deviate from the 1/f profile that characterises typical natural images (Juricevic et al, 2010, Perception, 39, 884-899). This study was conducted to determine whether the presence of uncomfortable stimuli has a negative effect on performance in a visual search task. We predict that, when presented with an uncomfortable background, observers will have a shorter reaction time to decide that a target is absent, so as to terminate the trial. Stimuli were initially vertical Gabor patches (of either 3 or 0.75 cycles/degree) presented against a random 1/f filtered noise patch, which subtended approximately 8 degrees. This was surrounded by either a mid-grey background, or a vertical sinusoidal grating of either 0.75, 1.5 or 3 cycles/degree that was irrelevant to the task. When the frequency of the grating matched that of the target, accuracy reduced and reaction times increased, in comparison with performance against a mid-grey background. The detrimental effect on performance was greatest when the Gabor and the background were closely matched for spatial frequency, i.e. it showed clear spatial-frequency tuning. This indicates that the effect is due to interference between the target and background. This was further supported by the fact that, when a horizontally-oriented target was used, spatial-frequency tuning was not found, and performance was no worse than that against a mid-grey background. It is concluded that the detrimental effects on performance did not reflect the apparent discomfort of the stimuli, but instead are due to interference between the target and background. This indicates that uncomfortable stimuli do not affect performance on a visual-search task, in a sample drawn from the general population.

Acknowledgement: BBSRC

Visual search: Eye movements

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

36.529 **Timing of saccadic eye movements during an accumulative visual search task**

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Efficient visual search requires rapid sequences of decisions about where to look, and when to initiate each saccade. To study temporal aspects of saccadic decisions, we used an accumulative visual search task in which several targets (thin outline circles, line width 4') were located in arrays of distractors (line width 5'-7'). Each target contained a randomly-oriented line (discernible only when fixated) and Ss reported mean line orientation at the end of trials. Durations of fixations varied according to the type of fixated location, with fixations on targets lasting ~40% longer than those on distractors. The same was found in control ("look-only") trials when orientation was not reported. The longer fixations may have aided search in that saccades launched from targets were more likely to land on targets than saccades launched from distractors. When fixation duration was prolonged by increasing the difficulty of the perceptual task, the probability of landing on targets also improved to some degree. Fixation durations also varied according to where the saccade landed. Saccades made from distractors to targets had shorter latencies, and smaller sizes, than saccades made from distractor to distractor. This suggests that saccades were delayed when a target was not immediately visible, but not delayed past the point of diminishing returns. Fixation durations increased with trial length and over time within trials, as the number of locations previously visited increased, producing a greater demand on memory in order to avoid revisiting targets. These results suggest that saccadic timing is modulated to produce efficient search. Searchers neither make saccades at highest possible rates, in the hope of reaching many targets through exploration, nor delay saccades past the point where useful information is likely to be obtained. Instead they adopt a strategy that takes into account the requirements of foveal processing, the difficulty of peripheral selection, and the momentary memory load.

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36.530 **Hide and Seek: Amodal Completion During Visual Search**

Robert Alexander[1](robert.alexander@notes.cc.sunysb.edu), Gregory Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

Previous work suggested that objects in search displays are preattentively completed behind occluders, but these studies were confounded in that occluded targets were identical across entire blocks—amodal completion may have occurred for the target representation used to guide search rather

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than preattentively for objects in the search display. To explore this possibility, we created four-item search arrays consisting of real-world objects, and systematically varied whether the search target was occluded or not at preview and in the search displays. We found that target verification times (the time between fixating the target and making a present/absent button press) were longest when the preview was unoccluded but the target in the search display was occluded (p <.001). This is consistent with a verification process that checks for specific features of the target, half of which may be hidden by an occluder. Guidance, measured as the percentage of initial saccades directed to the target, was strong when the target was occluded at preview but not in the search display (59%), which did not differ from a baseline condition having unoccluded targets during preview and search (63%; p= .87)—occluding a target at preview did not significantly weaken guidance. However, guidance was weaker whenever the target was occluded in the search display, regardless of whether it was occluded during preview (40%) or not (37%). If amodal completion occurs preattentively, we should not have found this ~20% guidance difference (p < .001) between occluded and unoccluded targets in the search display. In two control experiments we determined that these effects were not specific to our occluders or stimuli. Contrary to previous reports, these findings suggest that participants complete the target during preview, but that amodal completion does not occur preattentively during search, at least for the photorealistic objects used in this study.

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36.531 **Search is guided by two targets: Evidence from a combined fMRI and eye movements study**

Anna Huang[1](annasonghuang@gmail.com), Joseph Schmidt[1], Hyejin Yang[1], Hwamee Oh[1], Hoi Chung Leung[1], Gregory Zelinsky[1]; [1]Department of Psychology, Stony Brook University

Previous work has shown that searching for two targets is less efficient than for one, but why? One possibility is that people abandon one object and guide their search as if there were only one target. Another possibility is that both targets are represented and used for guidance, but that they lack the detail of a single-target representation due to visual working memory (VWM) limitations. To disentangle these hypotheses, we monitored eye movements during search for one versus two real-world targets inside of an fMRI scanner. Participants were first shown a preview display consisting of two images, either one target (shown twice) or two different targets, then a search display after a 9-second delay. One of the two images from the preview was always present in the search display, and the task was to look at the target and press a button. Behavioral analyses revealed that search guidance (percentage of trials in which the target was the first object fixated) was lower for two-target trials (47%) compared to one (67%). If this two-target cost was due to participants representing only one of the previewed objects, we would not expect to find a load effect in brain activity. However, fMRI data revealed greater delay period activation in the lateral and dorsal prefrontal and posterior parietal cortices, all regions previously associated with working memory maintenance loads (Leung et al, 2002, 2004). Moreover, we also found delay period activations in both lower- and higher-order visual regions. These results show that both targets are represented and used to guide search, and suggest that the guidance cost associated with two-target search is likely due to a VWM limitation. For one-target search, sufficient features are coded to yield a good guiding representation, whereas for two-target search, VWM limitations prevent the sufficient coding of features, resulting in weaker guidance despite more brain activity in visual areas.

Acknowledgement: This work was supported by NIH grant R01-MH063748 to GZ.

36.532 **Searching Through the Hierarchy: How a Target's Categorization Level Affects Categorical Search**

Justin Maxfield[1](jmaxfieldsbu@gmail.com), Gregory Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

Does the same basic-level advantage commonly observed in the categorization literature also hold for targets in a search task? To answer this question, we first conducted a category verification task to define a set of categories showing a standard basic-level advantage; for correct true trials the basic level was categorized the fastest (612ms), followed by subordinate (642ms) and superordinate (702ms) levels. We then created a search experiment using the same target categories and photorealistic objects, now arranged into six-item search arrays. Participants were cued with a category name at one of the three levels, and then shown a target-present/absent search display. Target-present displays included one target among five distractors drawn from different non-target superordinate categories. Target-absent trials contained five such distractors along with a single lure at the same hierarchical level as the target. For target-present trials, we found that the time between search display onset and fixation on the target, our measure of search guidance, was shortest for subordinate cues (426ms), longer for basic-level cues (462ms), and longer still for superordinate cues (530ms). However, target verification, the time between target fixation and the button press, showed the standard basic-level advantage; basic (432ms) was faster than subordinate (492ms) and superordinate (522ms). For target-absent trials, gaze generally took longer to reach the lure, and this resulted in the basic-level advantage appearing in guidance (basic, 518ms; subordinate, 549ms; superordinate, 675ms), but not in verification (no reliable differences between levels). These findings demonstrate different hierarchical advantages for guidance and verification in categorical search. Search guidance shows a subordinate-level advantage; the more accurately a target template can be described, the better the guidance. Verification shows a standard basic-level advantage. Caution is therefore required when interpreting manual categorical search times, as they reflect a mixture of different and partially offsetting guidance and verification processes.

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36.533 **Does Context act like a Spatial Attentional Set?: Exploring attentional control during visual search in scenes.**

Jordan A. Bawks[1](8jab1@queensu.ca), Monica S. Castelhano[1]; [1]Psychology, Queen's University

Attentional control and attentional sets (Folk & Remington, 1994) have been extensively studied in visual search arrays as a selectivity mechanism for filtering out irrelevant information. In the current study, we explore whether such a mechanism could also exist during visual search in scenes. Research has shown that when people search for an object in a scene, they use context to narrow their search to specific regions where the target is likely to be found. The current study investigates whether context can act as a spatial attentional set, where different areas of the scene become more or less relevant depending on the search target. Participants searched for a target object in 24 real world scenes while their eye movements were tracked. On 50% of the trials, an irrelevant distractor object would unexpectedly appear. The distractor would onset 50ms after the first fixation began and would appear either in the target's context region (Within condition) half the time or in a different context region (Outside condition). The relevant scene context was based on the general placement of target object (lower, middle and upper regions). Fixation data was used to determine the proportion of trials in which a participant immediately fixated on the distractor (within 2 fixations). We compared the proportion of fixations in the Within and Outside conditions and found they were significantly more likely to immediately fixate on the distractor when it was presented Within context (57%) than Outside (33%, p<.001). These results are in line with previous work showing that sudden onsetting objects do capture attention in scenes (Brockmole & Henderson, JEP:HPP, 2005). However, the current study shows that this ability to capture attention is dependent on attentional settings and suggests scene context is used to focus attention on target object regions and suppress information from other regions.

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36.534 **On-Line Contributions of Peripheral Information to Visual Search in Scenes: Further Explorations of Object Content and Scene Context**

Effie Pereira[1](effie.pereira@queensu.ca), Monica Castelhano[1]; [1]Department of Psychology, Queen's University

Past research has shown that when no immediate visual information is available in the periphery, scene context typically dominates search strategies (Castelhano & Henderson, 2007). In contrast, other studies have shown that when peripheral information is available, object content plays a significant role in the selection of potential target locations (corresponding to high spatial frequency information; Parkhurst, Law & Niebur, 2002; van Diepen & Wampers, 1998). The present study examined how search strategies are differentially affected by scene context and the placement of object content.

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Participants searched for a target using a gaze-contingent moving-window paradigm. The participants saw the search scene foveally, while extra-foveally, the scene was manipulated across five conditions: (1)Full Scene: search scene excluding the target; (2)Fractioned Scene: search scene with clusters of objects removed; (3)Object Array: an array of the scene objects on a grey background; (4)Scene Structure: a structural representation of the scene; and (5)No Scene: a black screen. Thus, the Object Array provided only object content, the Scene Structure provided structural information without gist information, and the Fractioned Scene provided scene context with a smaller number of objects. As expected, search performance was best in the Full Scene condition and worst in the No Scene condition across eye movement measures. Interestingly, there were no differences found in latency to the target between Object Array and Fractioned Scene conditions, but both were slower than Full Scene. Because the Fractioned Scene stimuli do not include clusters of objects around the target, the pattern of results suggests an interaction between scene context and object content. The information provided by objects surrounding the target plays an important role in the selection of potential target locations. Further experiments will report on the role of target information in the periphery and its influence on the selection prioritization of object content based on scene context.

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36.535 **Guiding Attention in Realistic Scenes: Older Adults Capitalize on Context During Visual Search**

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Younger adults utilize known associations between objects and scenes to guide attentional deployment during visual search (e.g., Biederman, Mezzanotte, & Rabinowitz, 1973; Brockmole & Henderson, 2006a; Neider & Zelinsky, 2006b). While much has been learned about the age-related declines associated with visual search for perceptual features (e.g., Folk & Lincourt, 1996; Humprey & Kramer, 1997; Whiting et al., 2005), little is known regarding the ability of older adults to use higher level scene information to guide search processes. On the one hand, it is possible that older adults might be able to capitalize on object-scene associations in order to guide attention more efficiently and compensate for declines in the perceptual processes associated with search. In this case, object-scene information might be more useful for older adults than it is for younger adults. On the other hand, older adults have been shown to experience declines in explicit memory processes (Old & Naveh-Benjamin, 2008). Such impairment could hinder their ability to utilize well-learned object-scene associations to guide search. To differentiate between these possibilities, in two experiments we had younger and older adults search pseudo-realistic scenes for targets with strong or no spatial associations (see Neider & Zelinsky, 2006b, for details of the paradigm). Both younger and older adults exhibited reaction time benefits when searching for a target that was associated with a specific scene region. Eye movement analyses revealed that all observers dedicated most of their time to scanning target-consistent display regions and that guidance to these regions was often evident on the initial saccade of a trial. However, both the benefits and costs associated with the presence of target spatial constraints were larger for older adults, suggesting that they relied more heavily than younger adults on object-location associations to guide search processes towards the target.

36.536 **The influence of Experience upon Threat Assessment and Visual Search in Complex Scenes**

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Using scenes taken from the recent conflict in Afghanistan, we explored the search and eye movement behaviour of a group of military personnel as they assessed whether they believed that the scenes contained an Improvised Explosive Device (IED). The threat assessment was based on an evaluation of Threat Indicators (TIs) during examination of each scene. There were two types of TIs: Physical TIs, which consisted of signals such as footprints or signs of digging indicating that an IED had been emplaced within the environment (by being dug into the ground); Psychological TIs, which consisted of areas in the scene that an enemy may be situated in preparation for an attack, or locations where an enemy may be situated in preparation to remotely detonate an IED. Our study had two goals. The first was to determine whether participants searched both Physical and Psychological TIs when reaching threat assessment decisions. The second was to determine if and how experience (in terms of searching for threat in live combat environments) modulates threat assessment search, both in terms of behavioural responses, and in eye movement behaviour. We found that both experienced and inexperienced participants examined the TIs in a similar manner, though inexperienced participants made more revisits to TIs, had longer response times, and showed evidence of a significant bias towards assessing the scenes as containing a threat. The results suggest that in tasks of this nature, the inexperienced participants were searching under the assumption that each scene would contain a threat, resulting in a significant bias in their responses.

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36.537 **Weaker interference from non-targets, rather than novelty, makes a reversed letter easier to find in visual search**

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It is easier to find a mirror reversed letter among its normal letter counterparts than vice versa. This is called the reversed letter effect. Traditionally, this has been explained by considering novelty, associated with a reversed letter, as a salient feature in visual search. Recently, using letter N and its mirror and/or rotated images as items in visual search stimuli, Zhaoping and Frith (2011) showed that the reversed letter effect is due to a task interference. This interference arises when mirror images of the target are present among non-targets, causing observers to confuse the target with these non-targets since shape recognition is typically viewpoint invariant. This interference is often manifested in a prolonged duration between the time when the gaze first located the target and the time when the search task decision is reached, occasionally causing gaze to abandon the target to search elsewhere. The interference should occur more quickly when searching for a more familiar target, since a familiar viewpoint speeds up shape recognition, thereby generating the reversed letter effect. We tested this further using eye tracking on general search stimuli, controlling whether any non-targets were mirror images of the target. No significant search asymmetry between reversed and normal letters was found when mirror images of the target were absent. This suggests that a reversed letter is not more salient. Furthermore, reaction times to find the target increased when its mirror images were among the non-targets, less so when the target was a reversed than a normal letter. Hence, a reversed letter target induces a weaker interference, rather than reducing reaction time by its novelty. The interference by mirror image non-targets was present even in observers with insignificant reversed letter effect, and even when some non-targets were not reversed letters for a normal letter target and vice versa.

Acknowledgement: Tsinghua University 985 fund, Gatsby Charitable Foundation

36.538 **Visual surveillance: What limits the perception of instantaneous information in dynamic displays?**

Nicole L Jardine[1](nicole-jardine@uiowa.edu), Cathleen M Moore[1]; [1]Department of Psychology, University of Iowa

We investigated causes of failures in a visual surveillance task. Observers searched for and reported the orientation of an oblique bar among vertical and horizontal distractor bars. Under standard (static) conditions, this is an easy task. However, adding frames prior to and after the target display changes the task into search for a single state of the bars within an ongoing dynamic display. We distinguish this as a surveillance task because it involves monitoring objects that change over time. Targets were black 45° (left or right) bars and distractors were black 0° or 90° bars. Static displays consisted of a single 150 ms frame in which the target appeared. Dynamic displays consisted of multiple 150 ms frames in which each bar rotated clockwise or counter clockwise, passing through the critical 45°/0°/90° orientations in the middle frame. Left/Right accuracy was 85% for static displays and 51% (near chance) for dynamic displays (Experiment 1). This failure in surveillance may depend on having to report a changing feature (orientation). To test this we altered the displays, which were otherwise as before, so that during the critical 45°/0°/90° frame, bars were 3 of 4 possible colors and the task was to report the color of the target bar (Experiment 2). Performance was much better (static: 94%, dynamic: 80%). Similarly, reporting the orientation of the target bars in the color-change displays (Experiment 3) also yielded improved performance (static: 92%, dynamic: 72%), though accuracy in this Left/Right task was still lower than when people reported color. The color-singleton status may guide attention to the target item, facilitating the extraction of the relevant information from temporally surrounding information more efficiently than when less guidance was available. Attentional guidance may be especially critical in surveillance because both spatial and temporal surrounding information can introduce distraction.

36.539 **Conjunction Search in Infants and Adults: An Eye Movement Study**

Christina Fuda[1](cfuda@yorku.ca), Scott Adler[2]; [1]Centre for Vision Research and Department of Psychology, York University, [2]Centre for Vision Research and Department of Psychology, York University

Visual search studies have shown that 3-month-olds exhibit "pop out" and feature search similar to adults (Adler & Orprecio, 2006), but that infants do not accomplish a conjunction search until around 6 months of age (Bhatt, Bertin & Gilbert, 1999). Previous conjunction search research with infants, however, has assessed their search behavior using habituation and preferential looking paradigms, which measure performance in seconds rather than milliseconds as is the case in studies of adults' search behavior. To allow for direct comparison of the two ages and comparable assessment of the relative development of search and attentional mechanisms, this study measured infant and adult saccadic latencies in milliseconds to localize a target in both conjunction and feature searches. Infants and adults were presented with either feature or conjunction visual search arrays at 3 different set sizes (5, 8, 10) with the target (a green or red "X" or "O") being either present or absent. Surrounding distractors differed based on a single unique feature (shape or color) or a conjunction of features (shape and color). Results indicated that both infants' and adults' saccadic latencies exhibited relatively flat functions across set sizes in the feature search, with infants' latencies being approximately 100 msec slower than adults'. In the conjunction search, in contrast, adults' saccadic latencies to localize the target increased as a function of set size, whereas infants' latencies did not increase with set size. Infants' latencies were also approximately 200 msec slower than adults' in the conjunction search. These results, consistent with previous studies, suggest a developmental progression in the capacity to conduct a conjunction search but that feature search is evident early in infancy. One possibility is that the attentional resources needed to allocate to the two features in the conjunction search have not yet fully developed at 3 months of age.

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Motion: Neural mechanisms and models

Sunday, May 13, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

36.541 **Psychophysical reverse correlation of motion perception**

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We used psychophysical reverse correlation to probe the mechanisms of motion processing. Specifically, we investigated whether short-range stroboscopic (apparent) motion processing can be explained by canonical motion processing mechanisms, or by a template-matching mechanism tuned to the apparent-motion stimulus. Observers were asked to detect a 3-step apparent-motion bar embedded in spatiotemporal Gaussian white noise. Half the trials contained the signal bar plus noise; the rest contained only noise. The ideal observer for this task is a linear template matched to the expected space-time locations of the bar, followed by a threshold. We estimated a linear and second-order kernel for each observer, using the maximum a posterior estimate under a generalized linear observer model (GLM), with a prior encouraging smooth and sparse filters. (These estimates were substantially better at predicting responses on held-out data than filters fit by "classical" psychophysical reverse correlation). The observed second-order kernels exhibited compelling direction selectivity (i.e., spatiotemporal orientation) and reveal integration across a larger range of spatiotemporal locations than the actual signal. Surprisingly, the second-order kernel alone provided a more accurate description of observers' data than the linear GLM, despite the fact that the target signal contained white bars only. To further analyze nonlinear contributions to motion perception, we reverse correlated observers' choices with the energy at each possible velocity in the noise from each trial. This analysis, using a radon transform to sum over all orientations in the Fourier domain, revealed perceptual filters tuned for the implied velocity of the apparent motion signal. Our results indicate that sign-invariant motion-energy calculations (Adelson & Bergen, 1985) underlie the detection of apparent motion, and demonstrates the feasibility of reverse correlation methods for analyzing the nonlinear mechanisms underlying motion processing in both psychophysics and physiology.

36.542 **The effects of dynamic background noise on speed perception**

Jason Chuang[1](chuang934@gmail.com), Xin Huang[1]; [1]Department of Neuroscience, University of Wisconsin-Madison

In natural scenes, objects commonly move upon cluttered backgrounds. Visual contexts can significantly influence motion perception. Here we investigate how visual contexts influence speed perception. We asked whether background-stimuli that did not move in a specific direction could influence the perceived speed of a center-stimulus. Visual stimuli were two overlapping random-dot patches. The diameters of the "center" and "background" patches were 5° and 7°, respectively. The random dots in the center patch moved coherently in a fixed direction at one of four speeds (5, 10, 15, 20°/s). The velocity of the random dots in the background patch was 0 (i.e. no net motion), but the motion coherence was set at one of several levels ranging from 0% to 100%. Human subjects performed a temporal 2AFC task to compare the speed of the center patch with that of a comparison patch. The speed of the comparison patch was varied from trial to trial and a matching speed was determined via a staircase procedure. We found that the perceived speed of the center patch was significantly faster than its veridical speed when the background contained random motion noise. The perceived speed was tuned to the coherence level of the background dots. The coherence level at which the perceived speed was the fastest shifted from high (i.e. less noisy) to low (i.e. more noisy) when the speed of the center patch changed from low to high. In other words, the effects of the background-stimulus on the perceived speed of the center-stimulus depended on the spatial-temporal characteristics of the center and background motions. We also found that these effects did not rely on whether the center-stimulus could be segmented from the background. These results suggest that speed perception is related to the overall motion energy within a specific region.

Acknowledgement: University of Wisconsin School of Medicine and Public Health, Department of Neuroscience, Graduate School, Wisconsin Alumini Research Foundation

36.543 **Perceptual transition dynamics of a multi-stable visual motion stimulus I: experiments**

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When an obliquely moving sine wave grating is presented inside a square aperture, observers are faced with a conflict of local motion signals resulting from the "aperture problem". Motion signals along the grating contours on average have a diagonal direction (D) while those near the horizontal (H) and vertical (V) edges lie along these cardinal directions. We explored the temporal evolution of this perception, which shifts regularly between the cardinal directions H and V as the dominant neural population serving conscious direction perception changes over time. We use visual psychophysics with eye movement recordings to extract and characterise the temporal signatures of this phenomenon and our companion theoretical work (II) builds a mathematical description of these dynamics. As with other motion stimuli exhibiting the aperture problem, ocular following trajectories are shown to reflect perceived direction. We look at how stimulus input parameters relating to the motion signal strength influence the frequency of reported transitions (H-V or V-H) and estimate a minimum period between switches of about 5s for slow moving stimuli (4-6deg/sec) with relatively low contrast. We design a task to capture the passive ocular following patterns over this extended presentation period of the order of 20s using frequent small amplitude saccades back to central fixation. The saccades avoid placing the fovea in close proximity of one of the edges and we find little evidence that they induce perceptual shifts. We describe ocular following patterns across observers, identifying alternative perceptual transition types which emerge in the companion theoretical treatment (II)

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and show varying extents of representation of D. The theoretical and experimental work converges to suggests an underlying dynamic adaptation of input strength dependent representations of the cardinal directions, H and V, which are mutually inhibitory and serve both eye movements and global direction perception.

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36.544 **Perceptual transition dynamics of a multi-stable visual motion stimulus II: modelling**

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We studied the temporal dynamics of perceptual switches that are known to occur during prolonged presentations of a multi-stable visual motion stimulus using a neural fields, population-level representation of cortical activity in the middle temporal (MT) visual area. The so-called ``barber pole'' stimulus is considered with an aperture configuration that supports horizontal (H), diagonal (D) or vertical (V) perceived directions for the same input. It was established in previous modelling work and psychophysical experiments that, for short presentations, there is a shift in perceptual dominance from D to either H or V with increasing duration. The experiments described in the companion experimental abstract (I) show that for longer term presentations on the order of tens of seconds, the perceived direction remains multi-stable, with perception switching every few seconds between H and V. Here, we present an extension our previous motion integration model with the addition of a firing rate (spike frequency) adaptation dynamic that enables switching between the mutually inhibitory representations of H and V. A parameter study is performed using the tools of bifurcation analysis and numerical continuation that shows the model supports two different switching characteristics. In the bump oscillation case, with more weight given to the local input, switches between H and V occur at regular intervals with a very fast transition between the two states. In the travelling wave case, with more weight given to lateral connections, switches also occur at regular intervals but the transition is slower and a wave propagates from H to V (or vice-versa) via the diagonal percept D. Interestingly, the experimental results (I) also show a range of subject responses with respect to the switching characteristic involving D as an intermediate percept; this suggests variable dynamical interplay between intracortical connections in MT and the input received from lower cortical areas.

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36.545 **Aging reduces surround suppression effects in a perceived speed task**

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In younger adults, direction discrimination for high-contrast patterns becomes more difficult as stimulus size increases (Tadin et al., Nature, 2003, 424, 312-5). Betts et al. (Neuron, 2005, 45, 361-6) found that this effect, known a spatial suppression, is reduced significantly in older adults, and hypothesized that this behavioural finding occurred as a result of decreased GABAergic inhibition in the aging visual system (Leventhal et al., Science, 2003, 300, 812-15). Recently, van der Smagt et al. (Vision Res., 2010, 50, 1900-4) found evidence for spatial suppression in younger adults using a task that measured the perceived speed, rather than the direction, of drifting gratings: perceived speed increased with stimulus size at low contrast, but decreased with increasing size at high contrast. The current experiment examined whether the effects of spatial suppression on speed judgments are reduced in older adults. Nine younger and 11 older subjects compared the speed of a drifting 1 cpd reference grating that varied in size (0.7 & 5 deg diameter) and contrast (2.8 & 92%) across conditions to the speed of a 1 cpd test grating that drifted at 2 deg/sec and whose size (0.7 deg) and contrast (38%) were fixed. Results from younger subjects replicated the main findings reported by van der Smagt et al., but the effect of stimulus size at high contrast was significantly smaller in older subjects. These results are consistent with the hypothesis that aging diminishes the effects of spatial suppression on motion tasks, although suppression may not change for tasks using static stimuli (Karas & McKendrick, J Vis, 2009, 9(5):11, 1-9; Farber et al., VSS 2010 & 2011) .

36.546 **Where two eyes are better than one for processing heading**

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Optic flow contributes importantly to visual navigation and perception of depth relations. So much so, that stereoscopic processing is often ignored in optic flow research although the natural stimulus consists of stereoscopic flow. Here we ask which parts of human visual cortex respond differently to monocular and binocular flow-signals. We investigated BOLD responses while subjects were exposed to wide-field (120x90 deg) presentation of the stimulus. Scanning was performed on a Siemens 3T (resolution 2.0 mm isovoxel, 32 slices, TR: 2000 ms, TE: 28 ms). To distinguish contributions of binocular summation and stereoscopic processing we presented in addition to monocular and stereoscopic also a 'synoptic' condition, in which both eyes were stimulated with identical patterns of flow on the retinae. We simulated forward motion (.25 m/s) through a 3D cloud (depth: 5m) of 300 points (150 dark and 150 light) on a grey background. To compare responses to self-motion patterns and to speed-matched incoherently moving dots, we rotated each motion vector by a random angle in the image plane (angular range dA: 0, 30, or 60 deg; lifetime: 1 s). We found clear differences between monocular and binocular conditions in several optic flow responsive areas: V3A, V6, MT+, VIP, and p2v. We found a large response increment to turbulent stereo flow in all motion-responsive areas and a specific response increment to forward motion (dA = 0) in p2v and VIP. These findings point to a widespread interaction between stereo information and local-motion in human cortex and a specific interaction of self-motion stimuli and stereo information in higher motion-areas p2v and VIP.

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36.547 **Resolving an occluded stimulus on the human cortical surface using pRF estimates**

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Introduction. Electrophysiology techniques in macaque parietal cortex (Assad & Maunsell, 1995) and fMRI experiments in human temporal cortex (Yi et al, 2008) have indicated a spatiotemporal continuity of visually evoked responses for moving, occluded stimuli. We sought to temporally and spatially resolve such a stimulus in early visual areas and to characterize the signal in the event of occlusion using pRF estimates (Dumoulin & Wandell, 2008). Our experimental goal was to determine whether we could resolve a moving, occluded stimulus within primary and extrastriate cortex. Methods. Subjects' brains were scanned with a 3 T MRI scanner and a 32-channel head coil. Standard retinotopic mapping and cortical flattening procedures were performed. The stimulus was a set of small (1˚) circular apertures traveling at a constant velocity and that bounce off the boundaries of the display and one another. Results. We were able to track the stimuli across the visual field in retinotopic coordinates among multiple visual areas. In addition, we computed the pRF estimates across visual cortex and used these to determine the response to both occluded and unoccluded moving stimulus across the cortical surface. Conclusions. We have demonstrated that the representations on the human cortical surface of moving stimuli and their interactions with occluders can be resolved at different velocities in multiple visual areas.

36.548 **Representation of stimulus features in V1 along the apparent motion path**

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Previous studies have shown that the perception of apparent motion leads to increased activation in the region of the primary visual cortex (V1) corresponding to the apparent motion path, suggesting that neural representation is reconstructed in the apparent motion path even at the earliest stages of cortical processing (Muckli et al., 2005). However, the question of whether visual properties of an object engaged in apparent motion are

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maintained in this representation remains unanswered. In order to examine this question, we used fMRI with pattern classification methods. During each trial, a bistable quartet with either left or right oriented gratings was shown. Subjects were biased to perceive either horizontal or vertical apparent motion. We extracted the BOLD signal in V1 corresponding to the middle location between the two gratings, containing the apparent motion path when the perceived motion was vertical, but not when it was horizontal. Our results show higher decoding accuracy of grating orientation when the regions between two gratings correspond to apparent motion path compared to when it does not. This suggests that neural representation reconstructed in the apparent motion path in early retinotopic cortex contains stimulus-specific information.

36.549 **The impact of optical blur on cortical responses to global form and motion**

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Visual event-related potentials (VERPs) have previously been used to study the development of form and motion processing in infancy. However, the extent to which infants' limited visual acuity might impact on their global form and motion processing is not fully understood. Previously, psychophysical coherence thresholds for both global form and motion sensitivity in adults were similarly resistant to blur with lenses of up to +12 dioptres (Braddick et al, Perception 36, ECVP Abstract Supplement, 2007). Our study assessed the effects of optical blur on steady state VERPs for coherent form and motion. Adult participants viewed concentric patterns of short arcs (form stimulus) or short motion trajectories (motion stimulus), each of which alternated at 2 Hz between 100% coherent and incoherent global organisation. VERPs were recorded for four levels of blur achieved using lenses of −0.12, +2.5, +5.5 and +10 dioptres. Increasing blur was associated with a progressive decrease in signal amplitude at the fundamental frequency (F1) for both form and motion stimuli, implying reduced responses to global coherence. This suggests that form and motion responses in populations with low acuity could be limited by this factor. The study highlights the need to take acuity into account when investigating form and motion responses in low acuity populations including infants and clinical groups. Future studies will aim to investigate impacts of blur on form and motion stimuli varying in spatial and temporal frequency, i.e. segment size and length (form), and dot size and speed (motion). This will help to determine the optimal stimuli to use for studying form and motion processing in low acuity populations.

Acknowledgement: The National Institute for Health Research, Special Trustees of Moorfields Eye Hospital, UCL Graduate School

36.550 **Neural correlates of induced motion revealed by fMRI.**

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A physically stationary stimulus appears to move in the direction opposite to surrounding motion (induced motion). Although previous studies have argued similarities between induced motion and surround suppression of direction-selective neurons in macaque areas MT and MSTl, the relationship between subjective perception of induced motion and cortical responses is still unknown. We addressed this issue by using functional magnetic resonance imaging (2-mm isotropic voxels, TR = 3 s) for human subjects. Visual stimuli were composed of a central Gabor patch surrounded by an annulus filled with a translating random-dot pattern (inducer). We examined how cortical activations differed depending on the velocity of the central stimulus; the velocity of the inducer was constant across conditions. The direction of the whole stimulus was changed every second within a 15-s stimulus block, each of which was sandwiched by rest blocks containing only the fixation point. We defined V1, V2, V3, and hMT+ based on activations in separate retinotopy and localizer scans, and determined the region of interest within each area by selecting voxels that showed significant responses to dynamic random-noise covering the central stimulus region. We found that hMT+ exhibited the greatest activation when the central stimulus moved fast in the direction opposite to that of the surround. More importantly, the hMT+ activation was the smallest when the central stimulus moved at the psychophysically determined cancellation velocity, at which induced motion was subjectively canceled. This pattern was consistently found in the two subregions of hMT+, namely TO-1 and TO-2 (Amano et al., 2009). Although V1, V2, and V3 showed similar patterns of activation, the compatibility with the pattern of induced motion perception was most pronounced in hMT+. The present results suggest that hMT+ is one of the neural correlates of induced motion perception and important for extracting object motions from a noisy background.

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36.551 **Effects of transcranial electrical stimulation on human motion detection**

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Transcranial electrical stimulation (TES) has been widely used for both clinical and basic neuroscience research purposes. Although its behavioral effects are evident from prior reports, our current understanding of the neural mechanisms that produce these effects in the intact human brain is very limited. We investigated the acute effects of transcranial alternating current stimulation (tACS, 0.5mA, 10Hz) on motion processing by stimulating over the relatively well explored human visual motion processing area, hMT+. We used a random dot kinematogram (RDK) stimulus presented at varying coherence to estimate the motion direction discrimination thresholds. We used a standard adaptation design with 4s of coherently moving dots as the 'adaptor' stimulus, followed by 1s of dots with varying coherence as a 'test' stimulus to measure the motion aftereffect. The storage of the motion aftereffect was estimated by delaying the presentation of the 'test' stimulus after the 'adaptor' by a fixed blank period of 4s. First, we found no evidence for a direct effect of TES over hMT+ on motion direction discrimination thresholds. Second, we found that TES reduced motion aftereffects when applied over the hMT+ area that was contralateral to the adaptor, but not when the stimulation was ipsilateral. Third, TES did not produce a significant extinction of storage when applied in the storage phase, between the 'adaptor' and the 'test' stimuli. This shows that changes in adaptation induced by TES only produced significant behavioral effects when the neurons were also driven by visual input. This suggests that TES could be targeted at cortical neuronal populations in an activity dependent manner.

Acknowledgement: Charles and Johanna Busch Foundation

36.552 **Shape-From-Motion is intact even when motion perception is impaired: a TMS study**

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Shape from motion (SFM) is a phenomenon that a spatial region is defined by 2D motion (typically moving random dots) and segregated from background as a shape. Because the shape in SFM is defined by motion, SFM perception supposedly coincides with MT+ activity as well as perception of motion. However, the temporal relationships between motion processing and SFM perception, and causal relationships between them are yet to be clarified. The main objective of this study was to investigate the temporal and causal relationships between motion perception and SFM perception. For this purpose, we examined the performance of SFM task while impairing subjects' motion perception by applying Transcranial Magnetic Stimulation (TMS) to MT+ (Beckers & Zeki, 1995). Prior to main experiment, 14 subjects underwent a MRI session, where the anatomical structure of the brain was obtained and the area MT+ was functionally localized for each subject. In the main experiment, single-pulse online TMS was delivered to the functionally localized MT+ at various timings from the stimulus onset (-120 ms to 320 ms). The stimuli were T or reversed T shape defined by moving random dots against static random-dot background. Subjects were asked to judge whether the shape moved either to the left or right (motion task), or whether the shape was either T or reversed T (shape task). The results revealed a clear dissociation between the performance of motion and shape tasks. The performance for motion task was impaired by TMS to the area MT+ at a particular timing. However, the performance for shape task was intact even when TMS was applied with the timing where motion task was severely impaired. These results indicated that perception of motion is not required for the perception of SFM, and suggest that a visual pathway bypassing MT+ contributes to SFM perception.

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36.553 **Cortical origin of contextual modulations in motion integration: linking V1 population response to the behavioral ocular following response**

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In psychophysics and physiology, it is well established that the contrast gain control is context-dependent. In both human and monkey ocular following studies, it has been shown that modulations of the contrast response functions (CRF) induced by a peripheral stimulus are delayed relative to center-alone conditions. We investigated the role of cortico-cortical interactions on this delayed contextual modulations using recording of population activity with voltage sensitive dye imaging (VSDI) in area V1 of behaving monkeys and investigated how much it could account for the one observed at the ocular following responses (OFR) stage. Dynamics of contrast response functions to a local stimulus were found to be very similar in V1 cortical activity and the OFR. At both levels, contrast gains increase over time in response to a single grating motion, with a latency difference of 20-30 ms. To probe the cortical origin of the contextual modulation of the contrast response function, we manipulated the peripheral stimulus distance and the stimulus scale. Our results in VSDI shows that the contrast-response function and horizontal spread are scale independent. However, scale differences were observed for surround-induced suppression. Small-scale stimuli were suppressed through a propagating wave of horizontal activity that spread from surround towards central representation. In contrast, at intermediate scale, we observed that an additional fast suppressive component was present at the very beginning of V1 response and in the OFR responses. However, the effect of peripheral distance was much weaker in the OFR response than in V1. Hence, effect of lateral distance on surround suppression in V1 and in the OFR is scale-dependent. The observed behavior seems to be a byproduct of a strong interplay among multiple regions such as V1, MT and presumably MST that would be recruited and interact differentially as a function of stimulus scale.

Acknowledgement: FACETS, BrainSCALES, Fondation des Aveugles de France

36.554 **A neural model of border-ownership and motion in early vision**

Arash Yazdanbakhsh[1,2](yazdan@bu.edu), Oliver Layton[1,2], Ennio Mingolla[2,3]; [1]Program in Cognitive and Neural Systems, Boston University, [2]Center for Computational Neuroscience and Neural Technology, Boston University, [3]Psychology Department, Boston University

Although models of figure-ground segregation often consider static scenes (Craft et al. 2007, J. Neurophysiology), the human visual system constantly deals with changes in light due to independently moving objects (IMOs), self-motion, and eye movements. Neurons (B cells) have been identified in primate visual cortex that are selective for border-ownership and integrate figural information from far outside their classical receptive fields (Zhou et al. 2000, J. Neuroscience). While there are often many sources of border-ownership information, humans perceive figure-ground relationships in moving random dot displays without structured patterns of luminance (Kaplan 1969, Perception & Psychophysics). Considering these challenges and spatio-temporal physiological properties of early visual areas, we developed a neural model of border-ownership to better understand figure-ground segregation in moving displays. Model LGN transient cells with different conduction delays (Maunsell et al. 1999, Visual Neuroscience) spatially integrate moving random dot input. We introduce units that detect spatio-temporal correlations independent of luminance magnitude by multiplicatively combining convergent LGN signals onto model V1 cells. Units compete across possible correlations in a recurrent competitive field configured as a winner-take-all network to locally determine the dominant direction of coherent motion. Grouping cells with larger receptive fields than model LGN and V1 units dynamically feed back to bias B cells in model V1/V2. Our model determines border-ownership signals at the edges of moving random dot and IMO displays due to the changes in spatio-temporal correlation separating regions perceived as figure and ground. Unlike other models that subtract different velocities to extract motion edges, our model results do not require the use of differential motion and predict that figure-ground distinctions could emerge shortly after LGN signals converge onto V1 cells. Consistent with Rucci et al. (2007, Nature), the model results predict that fixational eye movements enhance spatial contrast sensitivity, which is useful for determining figure-ground relationships.

Acknowledgement: Supported in part by CELEST (NSF SBE-0354378 and OMA-0835976) and ONR (N00014-11-1-0535)

36.555 **Speed tuning of cortical responses to 2D figures defined by motion contrast is non-uniform across contrast types.**

Jeremy Fesi[1](jdf232@psu.edu), Justin Stiffler[1], Rick Gilmore[1]; [1]Department of Psychology, The Pennsylvania State University

Motion contrast is important for object detection, yet sensitivity to its underlying spatiotemporal properties remains largely unexplored. Speed tuning may differ for figures defined by direction versus speed contrast, due to the distinct ecological context associated with each figure type (i.e., a moving object and motion parallax, respectively). However, similar response tuning for motion contrast magnitude has been observed across different types of motion-defined figures (Fesi et al., 2011), indicating that their cortical mechanisms may exhibit cue-invariance. In this study, we compared steady-state visual evoked potential (SSVEP) responses of n=20 adults (10 female, mean age: 19.5 yrs) to time-varying dot displays in which four figure regions emerged from and disappeared into background dots at a specified rate (1.2 Hz, F1). Figures defined by direction or global dot coherence contrast moved at 2, 4, and 16 degrees/s. Figures defined by speed contrast had background dots moving at 2, 4, and 16 deg/s, but featured a consistently faster figure speed relative to background. For the direction and coherence conditions, amplitudes at 1F1 peaked at 16 deg/s, while speed-defined figures elicited peak activation at 4 deg/s. Topographic maps of activation reveal a uniform medial occipital distribution of the 1F1 response for nearly all conditions, except for speed-defined figures. Here, the distribution shifted from medial occipital to centro-frontal channels as figure and ground increased in speed. Our results indicate that: 1) the processing of direction and coherence-defined figures are largely similar in terms of tuning and distribution along the scalp, and 2) responses for speed contrast are similar to those for other types of motion contrast, but only when figure and background move at slower speeds. This discrepancy may reflect sensitivity to the natural statistics of objects in central visual field, but also serves to qualify interpretations of cue-invariant processing of motion-defined figures.

36.556 **Time-To-Contact estimation in the ViSTARS model of primate motion processing**

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The time-to-contact (τ, TTC) between an observer and the environment can be derived from visual information and is highly advantageous for obstacle avoidance. In general, we should turn more quickly away from objects that we are likely to hit sooner. If expansion rate (E) defines the stimulus growth rate in the image plane then TTC = 1/E. The ViSTARS model (Browning et al., 2009, Neural Networks) demonstrated how motion information may be processed in the brain to detect and avoid obstacles while navigating towards a goal. The steering behavior of ViSTARS is similar to humans in simulated obstacle avoidance tasks, in some limited environments. ViSTARS did not include TTC estimates resulting in a turn-rate proportional to object size rather than to TTC. I present an updated ViSTARS model that accurately estimates the expansion rate of an object in model MSTd through the same mechanisms that are used to estimate heading. Model MSTd consists of a template match between an aperture resolved motion estimate in model MT+ and template cells sensitive to global motion in a particular direction. A recurrent competitive field configured as a winner-take-all network then accurately detects the current heading. Inclusion of inverse-distance weighting in the templates allows the neural circuit to explain human heading estimation bias in the presence of independently moving objects (Layton et al., 2011, VSS). The present analysis demonstrates that, if properly configured, this inverse distance weighting also allows model MSTd to provide accurate expansion, and by extension TTC, estimates when the stimulus fills the cell RF. Further updates to the

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template match, to compensate for regions containing no motion, provide size independent expansion responses. When the updated ViSTARS model is presented with frontal plane approach trajectories, MSTd produces accurate expansion estimates irrespective of RF or stimulus size and provides accurate TTC information to the steering module.

Acknowledgement: This work has been supported in part by the Office of Naval Research (ONR N00014-11-1-0535).

36.557 **Modeling a space-variant cortical representation for motion under continuous and phi motion conditions**

Jeremy Wurbs[1](jdwurbs@gmail.com), Ennio Mingolla[1], Arash Yazdanbakhsh[1]; [1]Cognitive and Neural Systems, College of Arts and Sciences, Boston University

V1 receptive field sizes increase with eccentricity, as does temporal processing speed (Carrasco et al. 2003, Hartmann et al. 1979). The fovea is evidently specialized for slow, fine movements while the periphery is suited for fast, coarse movements. In either the fovea or periphery discrete flashes can produce motion percepts. Grossberg and Rudd (1989) used traveling Gaussian activity profiles to model such apparent motion percepts as beta, phi, gamma, and the Ternus effect. We use physiological data to constrain a related model of how signals from retinal ganglion cells to V1 affect the percept of motion as a function of eccentricity. Our model incorporates cortical magnification (Dow et al. 1981, Wässle et al. 1989), receptive field overlap (Braccini et al. 1982, Stone 1965) and scatter (Dow et al. 1981), and spatial (Dow et al. 1981, Wässle et al. 1989) and temporal response characteristics (Baker&Braddick 1985, Hartmann et al. 1979, Ogawa et al. 1966) of retinal ganglion cells for cortical processing of motion. Following Baker and Braddick (1985) in our model D-max and D-min increase linearly as a function of eccentricity. Baker and Braddick (1985) make qualitative predictions about the functional significance of both stimulus and visual system parameters that constrain motion perception, such as an increase in the range of detectable motions as a function of eccentricity, a decrease in D-max as a function of input discretization, and the likely role of higher visual processes in determining D-max. We generate analogous quantitative predictions for those functional dependencies on individual aspects of motion processing. Simulation results suggest involvement of extrastriate areas in determination of values for D-max, but not D-min, which can be fit using only parameters from the retina through V1. Additional simulations indicate that D-max increases as a function of the number of frames, saturating after a few frames.

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36.558 **Modelling adaptation using the Adelson-Bergen energy sensor**

George Mather[1](gmather@lincoln.ac.uk), Andrea Pavan[2], Adriano Contillo[2]; [1]Psychology, University of Lincoln, UK, [2]SISSA, Italy

The motion energy sensor (Adelson & Bergen, 1985, JOSA, A2, 284-299) has been shown to account for a wide range of physiological and psychophysical results such as motion direction discrimination (e.g. Georgeson & Scott-Samuel, 1999, Vision Res. 39, 4393-4402). It has become established as the standard computational model for retinal movement sensing in the human visual system. The basic model can be implemented efficiently in Matlab® code. Adaptation effects such as threshold elevation and changes in perceived direction have been extensively studied in the psychophysical literature, but current implementations of the energy sensor do not provide directly for modelling adaptation-induced changes in output. We describe an extension of the model to incorporate changes in output due to adaptation. The extended model first computes a space-time representation of the output to a given stimulus, and then a simple RC gain-control circuit ('leaky integrator') is applied in the time domain (van de Grind et al., Vision Res. 44, 2269-2284). Model output shows effects which mirror those observed in psychophysical studies of motion adaptation: A decline in sensor output during continuous stimulation, and changes in the relative outputs of different sensors following this adaptation.

36.560 **Speed discrimination performance in adults but not children correlates with single-word reading rate**

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Adults with developmental dyslexia have poor speed discrimination performance (Demb et al. 1998; Eden, et al. 1996). We investigated whether there is a corresponding relationship between reading skill and speed-discrimination performance in children. We measured speed-discrimination, contrast-detection and reading in 28 subjects (14 adults, age 21-36; 14 children, age 6-16). Reading performance: Reading skills were assessed using an age-normed psychometric test of word reading efficiency (TOWRE) that measures the number of (1) frequent words, and (2) pseudowords, the subject can read in 45 seconds. Thresholds were assessed at mesopic luminance levels (4 cd/m2) in order to target the magnocellular pathway. Speed-discrimination: Drifting gratings (0.5 c/deg, contrast randomized between 16 and 24%, base speed 38 deg/s) were presented at fixation in two consecutive intervals. Observers indicated the interval containing the faster stimulus. Contrast detection: A grating (0.5 c/deg, diameter, 38 deg/s) with variable contrast was presented in one of two temporal intervals, and observers indicated the interval containing the grating. In adults single-word reading performance correlates with speed-discrimination thresholds (r = -0.617). In children, speed-discrimination thresholds are higher than adults (0.38°/s vs. 0.14°/s); performance does not correlate significantly with single-word reading (r=0.196). In both children and adults, pseudoword reading performance does not correlate significantly with speed-discrimination thresholds (r = -0.032; -0.135). In both groups single-word and pseudoword reading performance is independent of contrast detection threshold (adults: r=-0.137; -0.330; children: r=0.175; -0.104). The detection threshold levels are comparable in adults and children, (1.4%, 1.6%, respectively) indicating that speed discrimination differences are not explained by a general performance deficit in children. Hidden formatting deleted. Speed-discrimination is a late-developing perceptual skill (Ahmed et al., 2005; Ben-Shachar, et al. 2007). Speed-discrimination does not covary with reading performance during development.

Sunday PM

Monday Morning Talks

Perceptual learning: Models

Monday, May 14, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 1-3

Moderator: Daniela Pamplona

41.11, *8:00 am*

Neural Correlates of Learning During a Visual Search Task

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Performance on visual search tasks can be improved with training; however, the neural mechanisms underlying such improvement are not clear. For example, although response times (RTs) typically shorten with training, it is unclear which components of the stimulus-response processing chain are facilitated and lead to the faster behavioral output. In principle, enhanced search abilities could result from improvements in various distinct cognitive stages along the stimulus-response processing chain, including: (1) faster attentional shifts to the target, (2) faster or better discrimination of the target, (3) faster motor-response preparation, and (4) faster response execution. To explore the loci of cognitive and neural plasticity resulting from visual-search training, we measured EEG as individuals performed a multi-day visual-search training protocol. Over the course of five days, we assessed changes in RTs and in various stimulus-processing-related ERP components: the N2pc (attentional shifting to target), the SPCN (manipulation and/or retention of information in visual short-term memory relevant for target discrimination processes), and the LRP (preparation for motor response). Participants were presented with circular arrays of colored ellipses and reported the orientation of a color-popout target as quickly and accurately as possible. Across the training period, RTs decreased by ~70ms. ERP analyses indicated that neither the amplitude nor latency of the N2pc component changed, suggesting that the training-related RT improvement did not derive from accelerated attentional shifting. In contrast, the onset latency of the LRP shifted earlier, suggesting improvement on the processing between the attentional shift and the motor-response initiation. Relatedly, the SPCN decreased substantially in amplitude with training, consistent with a facilitated target-discrimination process. Lastly the time between the LRP onset and the RT decreased, suggesting additional training effects on motor-execution speed. The present results thus help delineate several key phases of the stimulus-response processing chain that underlie visual-search RT improvement with training.

41.12, *8:15 am*

Unnaturalness Modeling of Image Distortions

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Natural scene statistic (NSS) models are effective tools for formulating models of early visual processing. One area where NSS models have been successful is predicting human responses to image distortions, or image quality assessment (IQA) by quantifying unnaturalness introduced by distortions. Recent Blind IQA models use NSS features to form predictions of human judgments of distorted image quality without having available corresponding undistorted reference images. Successful learning blind models have previously been developed that learn to accurately predict human opinions of image quality by training them on databases of distorted images and associated human opinion scores. We introduce new NSS feature based blind IQA models that require even less information to attain good results. If human opinion scores of distorted images are not available, but a database of distorted images is, then opinion-less blind IQA models can be created that perform well. We have also found it possible to design blind IQA models without any source of prior information other than a database of distortionless "exemplar" images. An algorithm derived from such a completely blind model has only the distorted image to be quality-assessed available. Our new blind IQA models (Fig. 1) follow four processing steps (Fig. 2). Images are decomposed by an energy compacting filter bank then divisive normalized, yielding responses well-modeled as NSS. Either NSS features alone, or both NSS and distorted image statistic (DSS) features are used to create distributions of visual words. Quality prediction is expressed in terms of the Kullback-Leibler divergence between the distributions of visual words from distorted images and from the space of exemplar images. Both opinion blind and completely blind models compete well with standard non-blind metrics such as mean squared error (MSE) when tested on a large public IQA database (Tables 1 and 2).

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41.13, *8:30 am*

Perceptual learning of task mixtures

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Traditional perceptual learning has largely focused on learning of a particular stimulus and task. Understanding learning in more general contexts involving multiple stimuli and tasks requires us to study co-learning or interactions between learning of multiple stimuli. Several laboratories (i.e., Yu et al, 2004) report that mixing training – "roving" of stimuli – can disrupt or reduce learning. Perceptual learning in mixed stimulus conditions can be damaged unless tagged in an obvious way. In this experiment, we compare learning with several stimulus combinations intermixed over trials. Observers make orientation judgments (clockwise or counterclockwise) about sets of base angles (±12° about 22.5°, 67.5°, 112.5°, and 157.5°). Four intermixed base angles were each trained in one of four separate retinal locations; for intermixed pairs, each base angle condition was trained in two locations. A new integrated reweighting framework (Dosher et al., 2011) predicts that learning orientation identification in near base angles may interfere more with one another. So far as training stimuli are all mixed and learning happens within the same decision and reweighting structure, the demands of optimizing weights may interact. Orientation channels that weight towards CW for one reference angle may weight towards CCW for another adjacent reference angle. This predicts that roving two stimuli should lead to better learning for widely separated stimuli. The weights on orientation channels can be better optimized if more widely separated, i.e. for base angles 22.5° and112.5°. Our results support these predictions. Even when they occur in separate locations, orientation identification in widely separated base angles are learned far better than two near base angles, implying a role of location-independent representations in perceptual learning. These results also rule out the enhanced representation hypotheses, in which perceptual learning alters low-level representations in each location separately, and so predicts independent learning of each base angle.

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41.14, *8:45 am*

Comparing Reweighting Models in Perceptual learning: Optimal vs Proportional Hebbian

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Classical Hebbian models of learning depend on weighting sensory inputs on the basis of their association with the feature to be learned. Performance improvement due to reweighting mechanisms arises from a more optimal use of discriminating features in the stimuli. In the domain of perceptual learning, two distinct algorithms have been proposed for iterative reweighting of sensory data in the presence of feedback. The first algorithm is a Hebbian weighting increment that consists of the product of the sensory input and a feedback constant (Petrov et al., 2005; Dosher & Lu, 2009). The second is a Bayesian approach in which reweighting is seen as the process of using posterior probabilities, a non-linear function of the sensory data, as priors in subsequent trials (Eckstein et al., 2004; Trenti et al., 2009). The purpose of this study is to compare these models of reweighting with human-observers in a simple visual task. Three observers participated in yes-no detection of a contrast increment to a Gaussian spatial profile appearing at any one of four possible locations. Each location included additive Gaussian-distrib-

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uted contrast noise. When present, the increment appeared at the same location for a block of four consecutive trials. This allowed observers the chance to learn the relevant location and thereby exclude irrelevant locations from consideration, leading to improved performance. At the end of each block, subjects were asked to identify the target location as a secondary measure of learning. We find that for this visual task, classical models of learning based on a simple sensory-feedback product do not capture the rapid gains in performance and magnitude of noise-classification weights (Ahumada, 2002) as well as the ideal Bayesian reweighting algorithm. Our results suggest that, at the behavioral level, the process of learning can incorporate optimal reweighting schemes that go beyond simple association.

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41.15, *9:00 am*

A Dual Process Model of Perceptual Learning

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Most current perceptual learning (PL) theories neglect several critical components of the cognitive architecture, including the necessary mechanisms for categorization, decision making, and top-down control. The resulting gap is evident in the mainstream models of PL, which can account for the gradual improvement in a fixed stimulus environment but not for the intricate patterns of specificity and transfer from one environment to another. The perceptual categorization (PC) literature has identified mechanisms that can fill this gap. The emerging consensus in this literature is that human category learning is mediated by multiple distinct (but partially overlapping) systems. One system is explicit, involves verbal rules, working memory, and executive attention. This system supports greater generalization to novel stimuli and tasks. Another system is implicit, learns stimulus-response associations via reinforcement learning, but generalizes relatively poorly. We propose a Dual Process Model of PL (Dimple) that integrates the influential selective reweighting model of PL (Petrov, Dosher, & Lu, 2005, Psychological Review) with the influential COVIS theory of PC (Ashby et al, 1998, Psychological Review). The selective reweighting model maps naturally onto the implicit system in COVIS. The innovation in Dimple lies in the explicit system, which operates on intermediate-level representations that give separate, controlled access to individual stimulus attributes such as orientation and spatial frequency (Olzak & Thomas, 1990, VR). Dimple also has a working memory layer that maintains and adjusts the current decision boundary. Top-down selection of spatial locations and stimulus dimensions is based on the normalization model of attention (Reynolds & Heeger, 2009, Neuron). The implicit system determines the fine-tuned performance after prolonged training in a given environment, whereas the explicit system supports much of the generalization to novel stimuli and tasks. Both are necessary to account for the full pattern of specificity, transfer, and various dual-training effects (Zhang et al, 2010, J. Neuroscience).

41.16, *9:15 am*

Specificity in texture learning is a result of uninterrupted stimulus repetition

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Practice is known to result in long term improvement in visual sensitivity. This perceptual learning was found to be ubiquitously specific to stimulus features. For instance, sensory improvements apply only for the trained retinal location and do not transfer across space. Here we ask whether specificity is inherent to perceptual learning, or, possibly, an outcome of the repetition-based training methods universally applied. In the experiments, spatial transfer was tested using the backward-masked texture-discrimination task (Karni & Sagi, 1991), in three main conditions: (1) standard, repetition based method; (2) dummy, background only, task-irrelevant stimuli interleaved with the trained stimuli to disrupt the repeated stimulation pattern; (3) local dummy, where the background texture presented in (2) was restricted to the trained target region. During 4 days of training at a single location, thresholds improved from 175ms to 75ms, with no significant differences between conditions. On the 5th day, target location was altered to test generalization. The standard repetition based method (1) showed the known specificity (thresholds increased to initial level). However, complete transfer to a new location was found with both (2 & 3) "dummy" methods, as learning thresholds remained low. Additional experiments showed that the transfer was not due to the increased temporal intervals between target presentations. Moreover, transfer was found with the standard method (1) but with target presented at one of two locations, showing the importance of target location, rather than task, consistency. Our results show that generalization of learning is obtained by breaking stimulus repeatability. Specificity is the outcome of enhanced local spatiotemporal-associations, once interfered with enables the learning of space invariant stimulus features. It seems that these associations are formed within a low level visual system, where information is locally encoded, over a time frame of a few seconds but malleable to interference.

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41.17, *9:30 am*

The statistics of looking: Deriving properties of retinal ganglion cells across the visual field

Daniela Pamplona[1](pamplona@fias.uni-frankfurt.de), Jochen Triesch[1], Constantin A. Rothkopf[1]; [1]Neuroscience, Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe University

The statistics of the natural environment have been characterized to gain insight in the processing of natural stimuli based on the efficient coding hypothesis. Regularities present in these images have been measured and neurons have been shown to reduce the redundancy present in these stimuli. This analysis has revealed that retinal Ganglion cells□ properties can be related to the second order dependencies present in natural images. Such analysis has used the convenient assumption that natural image data is isotropic across the visual field, giving up on this assumption has reveal important dependencies reflected by their neuronal coding . Here we consider and quantify precisely the second order dependencies in images of natural environments due to the imaging properties of a model eye. We generated artificial scenes with three-dimensional edge elements and quantified the resulting distributions of orientations by applying the perspective projection onto a sphere. These distributions show a strong influence of the imaging process on the statistics of the input to the visual system. Secondly, image data from a naturalistic virtual environment was obtained. The second order statistics were computed as a function of eccentricity and radial distance from the center of projection. This confirms strong dependencies of the second order statistics on the position across the visual field. Finally, we repeated the analysis to commonly used image databases including the van Hateren database and quantified the second order dependencies as function of the position across the visual field using a new parametrization of the power spectra. We conclude by providing a detailed quantitative analysis of the second order statistical dependencies of the natural input to the visual system and making predictions of the retinal Ganglion cells□ profiles as function of their position across the visual field. 1: Tolhurst (1992) 2: Ruderman, Bialek (1994) 3: Rothkopf, Weisswange, Triesch (2009)

Motion: Complex stimuli

Monday, May 14, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 4-5

Moderator: Stuart Anstis

41.21, *8:00 am*

The perceived motion of moving barber poles

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We introduce a stimulus whose perceptual properties call into question current models of first-order motion processing. This stimulus consists of a diagonal sinusoidal carrier grating with bars drifting up to the left, windowed by a raised, vertical, drifting sinusoid. In slow motion, this stimulus represents a row of barber poles with blurred edges moving either to the right or to the left on a gray background, with diagonal stripes inside the poles moving either upward, downward or not at all, depending on the relative speeds of the carrier and windowing gratings. Foveally, this stimulus can be perceived veridically. However, when viewed peripherally at high temporal frequencies (conditions expected to allow the first order system to dominate the motion percept), this stimulus appears to move as a whole in a consistent, often non-veridical, direction. When the diagonal bars are vertically stationary inside the barber poles, then (as one might expect) this stimulus yields pure horizontal motion. However, if the diagonal bars are moving with even moderate speed inside the barber poles, then the motion

Monday AM

evoked is vertical (up or down depending on the direction of motion of bars inside the pole) over a wide range of barber pole speeds. Why this is surprising: (1) Physically, this stimulus translates rigidly in a diagonal (feature-tracking) direction; (2) the vector average of the Fourier components of this stimulus is also non-vertical. Various models of first-order motion processing predict that the motion produced by this stimulus should be in one or another of these two directions. We infer instead that the direction of first order motion is strongly influenced by a "stream-detection" process sensitive to the orientation of contrast-defined stream-beds within which pattern motion is constrained to flow. Remarkably, this process is insensitive to the motions of the stream-beds themselves.

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41.22, *8:15 am*

No second-order motion system sensitive to high temporal frequencies

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The existence of a second-order motion pathway, distinct from both the first-order luminance pathway and the high-level feature tracking motion system, remains controversial. Two key arguments support its existence: second-order motion is perceived at temporal frequencies too high to be tracked and sensitivity is independent of the relative phase between superimposed luminance- and contrast-modulated gratings. The later argument is typically used to reject the hypothesis that the contrast-modulation contribution to motion is due to early nonlinearities introducing luminance artifacts. But this argument is only valid if the nonlinearities are homogenous across luminance motion detectors; it does exclude the possibility that compressive nonlinearities precede some luminance motion detectors and expansive nonlinearities precede others. In the current study, to neutralize the impact of such opposing nonlinearities, we superimpose a luminance-modulated grating with a high contrast contrast-modulated grating so that some luminance artifacts would sum with the luminance-modulated grating and others would subtract resulting in no net gain. The gratings were drifting in the same direction at a temporal frequency too high to be tracked (15Hz) and their relative phase was systematically varied. Observers were asked to null the net perceived motion by adjusting the contrast of another luminance-modulated grating drifting in the opposite direction. The contrast-modulation contribution to motion was estimated as the contrast difference between the two opposing luminance gratings when no net motion was perceived. Results showed no effect of phase and the contrast-modulation significantly contributed to motion when the contrast of the superimposed grating was low, but not when it was high (i.e. no net motion was perceived when both luminance gratings had the same contrast). We conclude that our sensitivity to contrast-modulated motion at temporal frequencies too high to be tracked is due to early opposing nonlinearities differing across luminance motion detectors, not to a second-order motion pathway.

Acknowledgement: This research was supported by the NSERC-Essilor Research Chair.

41.23, *8:30 am*

Motion from structure

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Surfaces that have different disparity in a static stereogram appear to move relative to one another when the observer moves relative to the stereogram. How does a stimulus with no moving parts give rise to apparent motion? At one level of explanation, a "motion from structure" (MFS) inference occurs because, in a real scene, the absence of relative motion (e.g. dynamic occlusion) in the proximal stimulus requires that surfaces move relative to one another. What mechanism(s) are responsible for this inference? MFS looks smooth and is visible for minute head movements, suggesting that it may be supported by a dedicated mechanism that combines 2D image motion (including zero-velocity motion) with represented depth structure to estimate 3D object motion per se. Extra-retinal signals might play a role. We conducted experiments in which observers translated their heads (45 cm side-to-side, 0.5 Hz oscillation) and adjusted the speed (gain) of a position-yoked figure that had crossed disparity a stationary background. Stimuli were dense RDS projected onto a screen at 200cm (60 Hz per eye, field sequential). The square was 46 cm wide at eye height, the observer standing. For both of two observers, and across four disparities (8, 16, 24, and 32 arcmin, or 14, 26, 37, and 46 cm in front of the screen, respectively), motion gain settings (on-screen motion/head motion) were consistently close to 50% of the prediction from geometry as specified by binocular disparity. However, apparent depths averaged 83% of the depth specified by disparity, so gain settings were also less than predicted from apparent depth. Accordingly, real stationary objects were positioned in front of the screen; they appeared to move against the head. Additional experiments presented stimuli against a blank background or moving relative to a stationary head. No single model fitted all data but several lawful principles emerge.

Acknowledgement: NIH R01-EY013988

41.24, *8:45 am*

The positional motion aftereffect is spatially selective in world coordinates

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That our world remains stable in the face of continual rapid eye-movements suggests that there exists in the brain a neural representation, or "map", that does not move with the eyes but remains solid in external world coordinates. However, evidence from psychophysical and imaging studies for such as map remains fiercely controversial. In this study we measured spatiotopicity with the classical motion aftereffect (MAE: illusory motion following adaptation to motion) and the positional motion aftereffect (PMAE: illusory shift in apparent position following adaptation to motion). Subjects adapted to small (1°) vertically aligned patches of gratings (1 c/deg), drifting in opposite directions at 3 deg/sec. They then made a 12° rightward saccade, after which test grating stimuli (same size and spatial frequency) appeared for 500 ms, in the same retinal or the same screen position (or both, with no intervening saccade). For the MAE subjects annulled the motion, for the PMAE they annulled the apparent spatial misalignment of the patches. The MAE was strictly retinotopic (confirming previous research), but the PMAE showed a strong spatiotopic component. We also measured the PMAE with test gratings that were apparently stationary (with illusory MAE annulled) and found that under these conditions, the effects were almost entirely spatiotopic, with no statistically significant retinotopic component. Similarly, with brief (50 ms) stationary test-stimuli (producing only weak illusory motion), the effects were largely spatiotopic. The results imply two causes for the PMAE: one an indirect consequence of the illusory motion of the MAE; the other direct adaptation of a spatiotopic neural map. Taken together, the adaptation results provide very clear evidence for the existence of a spatiotopic map, probably within the dorsal stream, that is highly susceptible to influence from motion.

Acknowledgement: ERC grant

41.25, *9:00 am*

Illusory biological motion in the periphery

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Recent theoretical computational models suggest that point-light biological motion patterns are recognized on the basis of motion- and/or form-based action templates, but there is debate as to whether these templates are derived from analysis of local spatiotemporal features (Giese & Poggio, 2003) or global body postures (Lange & Lappe, 2006). To investigate this issue behaviorally, we put local and global stimulus features into conflict using a point-light actor with the joints composed of drifting Gabor disks. We imposed joint movements and orientation signals extracted directly from a walker, but set each Gabor element to drift in the direction opposite to its joint movement. The speed of counteracting local (drifting) motion was varied. When presented in the periphery (20 deg) and with sufficient counteracting drifting speed, the walking animation perceptually stands still. If drifting speed is increased further, it remarkably reverses perceived walking direction. In Experiment 2, we show that biological motion perception is possible without changes in global body form. Nine Gabor disks were configured to the shape of a generic body posture and remained stationary throughout the animation sequence. To animate the stimulus, local motion and orientation signals derived from several different actions were introduced to the Gabor disks. When viewed peripherally, observers were very accurate at discriminating the facing direction, walking direction, and the action portrayed (walking, running, marching, dancing) solely on the basis of local spatiotemporal cues. In Experiment 3, we imposed global translation on the action stimulus used in Experiment 2. Observers can readily identify global translation directions and also simultaneously achieve good

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performance in biological motion tasks. Taken together, these experiments provide compelling evidence that local motion signals provide sufficient information to induce action templates that facilitate recognition of biological motion. Further, in the periphery motion-based analysis dominates when pitted against global body form.

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41.26, *9:15 am*

A Flicker Detector Model of the Motion Silencing Illusion

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The perception of motion and change are important mechanisms in a visual system. Suchow and Alvarez recently presented a “motion silencing” illusion, in which salient flicker (spatially localized repetitive changes in luminance, color, shape, or size) become undetectable in the presence of rapid motion. They also proposed a “misattribution” hypothesis, which we interpret to mean that, when there is an actual motion signal, the dynamic signal from the flicker is misattributed to the motion stimulus, and hence no flicker is perceived. In an attempt to understand this phenomenon, we have developed a model incorporating a novel luminance flicker detector. We conducted experiments examining the relationship between rotational velocity (RV) and change rate (CR). We also did a systematic spectral analysis of the stimuli over a wide range of flicker and rotation rates. We then used the distributions of the spectral signatures of the dynamically changing stimuli to develop a computational model of silencing under the assumption that there is a motion energy threshold beyond which all temporal energy is attributed to motion. The model accurately captures the quantitative relationship between RV and CR for silencing, in which linear regression parameters are almost identical between humans and the model. This implies the misattribution hypothesis is likely correct. Specifically, we posit that, given limited resources to detect temporal change, all temporal change is interpreted as motion when a certain amount of actual motion exists. This is understandable in an ecological context because the probable consequences of ignoring true motion (a “miss”) are likely much greater than misinterpreting flicker as motion (a “false alarm”) given the relative rarity and importance of stationary flickering stimuli in the natural world.

Acknowledgement: This work was supported by the Intel and Cisco Corporations under the VAWN program, by AT&T Corp, and by the National Science Foundation under Grants IIS-0917175 and IIS-1116656.

41.27, *9:30 am*

The Flash Grab Effect

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When an object moves back and forth, its trajectory appears significantly shorter than it actually is. The object appears to stop and reverse well before its actual reversal point, as if there is some averaging of location within a window of about 100 ms (Sinico et al, JEP:HPP 2009). Surprisingly, if a bar is flashed at the physical end point of the trajectory, right on top of the object just as it reverses direction, the flash is also shifted – grabbed by the object – and is seen at the perceived endpoint of the trajectory rather than the physical endpoint (Anstis & Cavanagh, VSS 2010). This shifts the perceived location of the flash by several times its physical size and by up to several degrees of visual angle. We measure the shifts in the perceived flash location and show that there is a small spatiotemporal attraction zone around the physical end point of the trajectory. Any flash falling in that zone is pulled toward the perceived endpoint. The effect scales linearly with speed and is independent of the contrast of the moving stimulus once it is above 5%.

Acknowledgement: Supported by Chaire d’Excellence ANR grant to PC and the UCSD Senate to SMA

Face perception: Mechanisms

Monday, May 14, 10:45 - 12:45 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Tim Andrews

42.11, *10:45 am*

Objective Measurement of Face Detection Thresholds using Sweep VEP

Justin Ales[1](justin.ales@gmail.com), Faraz Farzin[1], Bruno Rossion[2], Anthony Norcia[1]; [1]Stanford University, [2]University of Louvain

Face detection is fast, accurate, and seemingly effortless. Here we introduce a highly sensitive method to measure face detection thresholds rapidly, objectively and independently of low-level visual cues. The method is based on the swept parameter steady-state Visual Evoked Potential (SSVEP), in which a stimulus is presented at a specific (“tagged”) frequency while parametrically varying (“sweeping”) the detectability of the stimulus. For this experiment, the stimulus consisted of the appearance of a face image (F) from noise comprised of a phase-scrambled face image (SF) with an equal power spectrum and mean luminance. Alternations between the images (F-SF-F-SF-F-…) at a constant rate (3/second) elicited a robust odd harmonic response (3.0 Hz) specific to the structure of the face. The visibility of face images was increased by progressive de-randomization of their phase spectra in a series of equally spaced steps. Trials contained an ordered series of 20 levels of image degradation presented over 20 seconds. High-density EEG was recorded from 10 human adult observers. While face information was revealed only gradually in the stimulus, the evoked response at the first harmonic (3.0 Hz) emerged abruptly. The face-specific detection response was most prominent on right lateral occipito-temporal sites. Thresholds for face detection were estimated reliably from the emergence of the first harmonic response in single observers from 15 trials, or on each of the 15 individual face trials across observers in the study. The VEP derived thresholds correlated with the concurrently measured behavioral face detection times. This first application of the sweep VEP approach to high-level vision provides a sensitive and objective method that could be used to measure and compare visual perception thresholds for various object shapes and levels of categorization in different human populations, including infants and individuals with developmental delay.

42.12, *11:00 am*

Intra-cerebral electrical stimulation of a face-sensitive cortical area causes transient specific impairment in face recognition

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We report the first case of transient impairment in face recognition – prosopagnosia – induced by intra-cerebral electrical stimulation. The patient was a 32-year-old right-handed woman (KV) who has medically intractable right occipital epilepsy. She never complained of difficulties in face recognition and present with normal face recognition abilities. Intra-cerebral electrodes were implanted stereotactically to record seizures and to perform focal electrical stimulation in order to define epileptogenic and functional zones. During stimulations of right and left occipito-temporal contacts (biphasic pulse; 50 Hz train of 5 s; from 1 to 1.8 mA), she was asked to name previously correctly recognized famous faces, objects and scenes (Figure 1). Six of seven bipolar stimulations including one common contact (named O7; Figure 2) located within the right inferior occipital gyrus reproducibly induced transient prosopagnosia which completely recovered immediately upon termination of the stimulation. The patient reported a disturbance in perceiving the spatial relationship of facial elements and being unable to perceive the face as a whole. Stimulations at this site never produced visual distortions, deficit in object and scenes recognition or epileptic discharges. Stimulations of all other contacts and electrodes did not elicit prosopagnosia. The brain region of interest was mapped using fMRI and intra-cerebral

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ERPs by contrasting responses to pictures of faces and objects (Figure 2). The eloquent stimulation site O7 was located exactly within the right occipital face area (OFA). A N170 face-specific potential was also recorded at the stimulation site reinforcing the functional specificity of this area for face perception. We also found a N170 face-specific potential at an anterior site F6, located at the edge of the right FFA. However, its stimulation did not evoke any prosopagnosia. These findings provide evidences that the right OFA is necessary for normal face perception as part of a bilateral occipito-temporal network of face-sensitive areas.

42.13, *11:15 am*

Varying object identity while maintaining the continuity of its movement breaks position invariant perception

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We hypothesize that the visual system uses the temporal continuity of object identity to build position invariant object representation. This predicts that varying an object's identity while maintaining its continuity of movement will alter position invariance. Here, we tested this prediction for human facial gender perception. During an Exposure Phase, sixteen subjects covertly tracked smiles/blinks of a face (3 degrees in size) that continuously orbited around a fixation point (10 sec period, 5 degrees eccentricity). While orbiting, facial gender morphed alternately between female and male, becoming maximally female when crossing the position to the left of fixation (female pole) and maximally male at the position to the right (male pole). Subjects performed this task for 30 minutes broken into 6 minute blocks. Sixteen other subjects participated in a control condition in which the orbital path was broken along the vertical meridian into two alternating semi-circular paths. To test for the predicted experience-induced changes in position invariance, subjects performed a Discrimination Task judging whether the gender of two simultaneously presented faces – one at each gender pole – was the same or different (120 trials, 50ms presentations, eccentricity and size same as in Exposure Phase). We found that following the Exposure Phase, subjects tended to perceive faces as female at the male pole, and male at the female pole. This experience-induced perceptual bias was significantly stronger in the continuous condition (Exposure Phase) compared to the control condition, ruling out a simple adaptation explanation. The induced bias was attenuated but still significant 24 hours after the Exposure Phase. This suggests that the temporal continuity experience is strong enough to alter position invariant object judgments in <1 hour and this effect persists for at least 24 hours. We propose that the natural temporal continuity of objects in motion builds perceptual tolerance to translation.

42.14, *11:30 am*

Identity modulates pSTS response to changeable aspects of faces.

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Previous neuroimaging studies have shown that the posterior superior temporal sulcus (pSTS) is involved in processing changeable aspects of faces, such as expression and gaze direction. To be socially meaningful, however, such changes must be tracked across an individual. We therefore investigated the sensitivity of pSTS to facial identity while processing changeable characteristics of faces. We used fMRI to assess the neural responses in a large number of participants (N=103) viewing sequences of faces that varied in expression and viewpoint. There were two conditions: (1) same identity faces and (2) different identity faces. A whole-brain, group analysis revealed that the face-selective pSTS was more highly activated by same identity compared with different identity faces. In contrast, the face-selective fusiform face area (FFA) was activated more strongly by different identity than same identity faces. Because pSTS is not usually thought to encode facial identity, we sought to understand how the activation of the pSTS to changes in expression and viewpoint could be greater when faces have the same identity than when faces have different identities. We therefore measured how functional connectivity between core face-selective regions (OFA (occipital face area), FFA and pSTS) was affected by identity. We found a significant increase in the correlation of the residual time-courses between pSTS and OFA and between pSTS and FFA when participants viewed changeable aspects of same identity faces compared to different identity faces. There was no difference, however, in the functional connectivity between OFA and FFA when same or different identity faces were viewed. The identity-dependent change in connectivity between pSTS and other face-selective regions suggests that pSTS receives information about identity from these other regions, allowing it to process changeable features of the face in a socially meaningful way.

Acknowledgement: Wellcome Trust

42.15, *11:45 am*

The role of the pSTS in the pre-categorical coding of emotional expression

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Models of face perception suggest that information important for social communication (for example, facial expression) is processed in the posterior superior temporal sulcus (pSTS). Our aim was to determine the nature of the coding of facial expression in pSTS. In Experiment 1, fMR-adaptation was used to determine the sensitivity of pSTS to changes in facial expression and facial identity. Twenty participants were scanned while viewing faces in the following conditions: 1) same identity, same expression; 2) same identity, different expression; 3) different identity, same expression; 4) different identity, different expression. The pSTS was identified by an independent localiser scan in each participant. We found a release from adaptation in pSTS for changes in expression, but not for changes in identity. In Experiment 2, fMR-adaptation was used to investigate whether the coding of expression in the pSTS is categorical or continuous. Expression continua were generated by morphing between two expressions. From these morphed continua we selected within-category changes in expression (a 33% morph difference that did not cross the category boundary) and between-category changes in expression (a 33% morph difference that crossed the category boundary). Twenty-six participants were scanned while viewing faces in the following conditions: 1) same expression, same identity; 2) within-category expression change, same identity; 3) between-category expression change, same identity; 4) same expression, different identity; 5) within-category expression change, different identity; 6) between-category expression change, different identity. There was a release from adaptation for changes in expression, but not for changes in identity. Importantly there was an equivalent release from adaptation for within-category compared to between-category changes in expression. Our results show that pSTS is more sensitive to changes in expression than identity, and that its coding of expression is continuous rather than categorical. These findings are consistent with pSTS having a role in pre-categorical analysis of expression.

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42.16, *12:00 pm*

Gender-selective neural populations within the occipital and fusiform face-areas: Evidence from rapid event-related fMRI

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Facial features provide salient cues about the gender of another individual – information that is critical for human social interaction and mate selection. Although much is known about the neural representation of face and body information in ventral temporal cortex, surprisingly little is known about the neural circuitry supporting the recognition of gender. We used rapid event related fMRI adaptation to examine neuronal sensitivity to facial gender-based cues within face- and body-selective regions of ventral temporal cortex. Each trial involved a brief (400ms) presentation of two consecutive greyscale images of faces. In the 'Different' condition, paired images each depicted an individual of a different gender (i.e., male - female). In the 'Identical' condition, the images consisted of individuals of the same gender (i.e., male - male). Importantly, facial identity was not repeated within or across trials. The participant's task was to make an orthogonal attractiveness rating on randomly occurring trials within each scan, which were later excluded from data analysis. We used an independent task to functionally localize facial identity-selective and body-selective

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areas within ventral temporal cortex of each observer. Changing the gender of the face on 'Different' trials produced significant release from adaptation within both the occipital and fusiform face areas. Conversely, we did not find evidence for gender-based sensitivity within neighboring extrastriate and fusiform body-selective regions. Our results indicate that neuronal populations within ventral temporal face-selective cortex are sensitive to gender-based information provided within facial images. This selectivity occurs independently of changes in facial identity. The same gender-based cues do not, however, appear to transfer across-category to neighboring body-selective areas.

42.17, *12:15 pm*

Happily surprised or angrily surprised: A cognitive model for the recognition of a large number of facial expressions of emotion

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The understanding of emotion perception is of fundamental importance for the advance of cognitive and vision science. Yet, research on the production and perception of facial expressions of emotion has focused on the representation and recognition of six basic emotions – happy, sad, angry, surprise, fear and disgust. Muscle groups (i.e., Action Units, AU) involved in each of these emotions have been identified. Also, two cognitive models have been proposed for the representation and recognition of these six emotions. The continuous model represents each facial expression as a feature vector in a common face space. The categorical model defines a classifier for each of the emotion labels. Unfortunately, the current definition of these models does not account for the representation and recognition of compound emotions, e.g., happily surprised, angrily surprised, fearfully surprised, or hatred (which is defined as feeling anger and disgust toward someone). We have collected a large dataset of 25 distinct facial expressions of emotion from a total of 100 individuals. We have identified the common AUs for each expression and defined a hybrid continuous-categorical model that explains how such a large number of expressions can be represented and recognized. In the proposed model we do not need to train 25 distinct classifiers as in the categorical view. Instead, we show that by linearly combining a small number of classifiers, the model can readily represent and recognize a very large number of emotion categories. This also resolves the problem of the continuous view, where happily surprised and angrily surprised would be represented as disjoint areas of a continuous face space even though they both express surprise.

Acknowledgement: National institutes of Health R01-EY-020834, R21-DC-011081

42.18, *12:30 pm*

Neural correlates of the own-race bias in face recognition memory: Evidence from event-related potentials

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Participants are more accurate at remembering faces of their own- relative to another ethnic group (own-race bias, ORB). Here, we examined event-related potential (ERP) correlates of this effect in an experiment testing recognition memory for Asian and Caucasian faces in Caucasian and Asian participants. Asians had been living in Germany for at least six months (mean = 22 months) and thus had considerable expertise with Caucasian other-race faces. While both Asian and Caucasian participants demonstrated more accurate recognition memory for the respective own-race faces, the size of the own-race bias was significantly larger for Caucasian participants. Test phase ERPs revealed more negative N170 amplitudes for other-race faces in both participant groups, probably reflecting more effortful structural encoding. The subsequent occipito-temporal P2 yielded significantly more positive amplitudes for own-race faces in Caucasian, but not in Asian participants. This is in line with recent results, demonstrating ethnicity effects in P2 in those participants without substantial expertise for other-race faces only. Additionally, the magnitude of the P2 ethnicity effect correlated with the difference in self-reported contact quality towards own- and other-race persons. Finally, in the subsequent 280-400 ms time window (late N250), both groups demonstrated more negative amplitudes for the respective other-race faces at occipito-temporal channels, and this ERP effect of ethnicity was found to significantly correlate with the own-race bias in recognition memory. In sum, these findings suggest an influence of ethnicity on face processing starting at early structural encoding stages in the N170 time range. Individual experience, as indicated by self-reported quality of contact, affects later and more fine-grained stages of perceptual processing reflected in the P2. Crucially, ERP effects in the 280-400 ms time window presumably represent the processing of individual identity of the presented faces, and are thus directly related to the behavioral ORB in recognition memory.

Acknowledgement: Funded by DFG grant Wi 3219/4-1

Development and plasticity

Monday, May 14, 10:45 - 12:45 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Bosco Tjan

42.21, *10:45 am*

Functional organisation of visual pathways in a patient with no optic chiasm

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Background: Patients with albinism or congenital achiasma offer a unique opportunity to study cerebral reorganization and inter-hemispheric communication in the face of highly anomalous inputs to striate cortex. Objective: We describe neuroimaging studies in a patient with congenital achiasma and seesaw nystagmus, but full visual fields. Methods: The subject underwent structural MRI, DTI studies, and functional MRI with monocular stimulation with light/dark checkerboards, motion, and objects and faces, as well as retinotopic quadrantic stimulation. Results: Structural MRI confirmed the absence of an optic chiasm, which was corroborated by diffusion tensor imaging (DTI). Monocular full-field presentation of chequerboards resulted in activation restricted to the ipsilateral primary visual cortex, providing functional confirmation of a lack of crossing visual inputs to striate cortex. Areas V2 and V3 also showed activation only by the ipsilateral eye. Additional analysis showed no difference between the on and off conditions in the contralateral visual cortex, indicating no sub-threshold activation in V1-V3 and confirming a true lack of response to visual stimulation. Monocular retinotopic stimulation of the left and right visual fields further showed reorganisation within primary visual cortex. Monocular presentation of motion versus static stimuli revealed bilateral activation in the area V5 complex by stimuli presented to either eye, Similarly monocular presentation of faces and objects produced bilateral activation in the posterior and middle fusiform gyrus. Conclusions: These results show the functional reorganisation of striate cortex to anomalous monocular full-field input and indicate that inter-hemispheric integration of information does not occur at early V2/V3 levels, but at an intermediate stage (V5) and higher levels (fusiform gyri).

Acknowledgement: JB was supported by a Canada Research Chair

42.22, *11:00 am*

Visual cortex representation of achiasmic retinal inputs

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In achiasmia (absence of optic chiasm), the nasal retina is abnormally projected to the ipsilateral hemisphere such that the LGN and early visual areas in one brain hemisphere receive retinal inputs of the full visual field of the ipsilateral eye. This rarely diagnosed condition presents a unique opportunity to study common developmental rules of the visual cortex, which maintains a topological map of retinal inputs. A 23-year-old male with a congenital nystagmus and achiasmia (confirmed with MRI) was evaluated using BOLD fMRI. The participant monocularly viewed visual stimuli, which included a rotating wedge and an expanding ring for retinotopy, an expanding-contracting ring and a stationary ring to map MT/MST, and rapidly presented faces, scenes, objects, and scrambled images to map LOC. Resting-state data was also acquired while the participant closed his eyes but stayed awake. The obtained retinotopy was of excellent quality. Within the retinotopically defined visual areas V1– V3, the participant's retinotopic representation of the ipsilateral visual field is a mirror image of its contralateral field representation. The two are superimposed on the ipsilateral hemisphere of each eye such that two points symmetrically located across the vertical meridian are mapped to the same point on the cortex, consistent with a recent study (Hoffmann et al., 2011 SfN). With monocular viewing, activations of V1-V3 are limited to the ipsilateral hemisphere relative to the viewing eye. In contrast, activations of MT and LOC are bilateral, as in normally sighted individuals. Moreover, even though evoked activities in V1-V3 are unilateral to the eye of origin, the resting-state activities in these areas showed the normal high correlation (r=0.6-0.9) between the hemispheres. These findings suggest that while the early visual areas develop according to the abnormal topological organization of the retinal projections, later stages of visual processing have "fixed" the topological abnormality.

Acknowledgement: NIH/NEI research grant R01-EY017707

42.23, *11:15 am*

Brain morphological changes associated with normal aging in the early visual cortex

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While a growing body of evidence suggests the age-associated reduction of global and regional thickness in the brain (eg. Lemaitre et al., 2010), it is not completely understood how aging affects the structure in the early visual area. Here, we tested whether aging affects surface size and/or thickness in the early visual areas, and if so, whether the cortical size and/or thickness in the early visual areas is correlated with performance on visual tasks with older people. We conducted a standard retinotopic mapping by 3T MRI in older (n=15, 65-86 yr) and younger participants (n=9, 19-28 yr) individually to localize V1, V2 and V3 in a flattened format of the cortical surface. Then, we measured the areal cortical surface size as well as the thickness in V1, V2 and V3 in each hemisphere. Moreover, we conducted 2 types of visual tasks with older participants: the texture discrimination task (Karni and Sagi, 1991), one of the standard visual perceptual learning tasks, and the useful field of view test (Roenker et al. 2003), a standard measure of attentional processing in older people. We found that the areal surface size in V1, V2, and V3 in the older participants was significantly smaller in comparison with the younger participants. In contrast, the cortical thickness did not display any significant age-related changes. Importantly, only the surface size of V3 was significantly correlated with the amount of improvement in the perceptual learning task, but not in the attention task, in the older participants: The larger size of V3 is associated with higher improvement after the 3-day training. These results clearly demonstrate the age-associated reduction in the early visual cortical surface space but not thickness, and further suggest that V3 area may play an important role in visual plasticity in older people.

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42.24, *11:30 am*

Overlap but not interact: fine grain organization of neural populations in the visual cortex of achiasmia revealed with long-term fMRI adaption

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In achiasmia (lack of optic chiasm), each brain hemisphere receives retinal inputs of the full visual field from the ipsilateral eye. Testing a 23-year-old male with achiasmia (confirmed with MRI) revealed that the retinotopic representation of the ipsilateral visual field in V1-V3 is a mirror image of the contralateral field representation. The two are superimposed such that two symmetrical points in the visual field across the vertical meridian are represented at the same cortical location. Nevertheless, psychophysical testing showed no detectable interaction between the left and right visual field, suggesting that even though the neurons with receptive fields in different hemifields are closely packed in V1-V3, they do not interact. We tested this hypothesis with a long-term fMRI adaptation paradigm (Fang et al., 2005, 2007). The subject was tested monocularly while performing a demanding fixation task. The adaptor and test stimuli were counter-flickering Gabors presented in the lower field on either side of the fixation. As expected, we observed in V1-V3 a release from adaptation when the test was at the same location as the adaptor but with orthogonal orientation. Critically, we also observed a release from adaptation when the test was at the location symmetric to the adaptor across the vertical meridian, irrespective of orientation. For V2 and V3, the amplitude of release for a symmetric-location test was the same as for the same-location test with orthogonal orientation. For V1, however, the release for the symmetric-location test was significantly higher than the same-location orthogonal test. These results are consistent with the hypothesis that inputs from the different hemifields might be organized in columns akin to the ocular dominance columns (ODC) in V1, which are coarser in size than the orientation columns. Such "hemifield dominance columns" disappears in V2 just as ODC is absent from V2 in normally sighted individuals.

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42.25, *11:45 am*

The Correlation Between Accommodation and Vergence Responses in Three-Month-Old Human Infants

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Purpose: Classical models of accommodation and vergence incorporate a number of components either in the context of the Maddox/Heath classifications (blur-driven, disparity-driven, tonic, coupled, proximal and voluntary) or Controls Theory models (phasic, tonic, coupling and plant). In either vocabulary, these components may combine with different weights to generate relatively coupled or independent motor responses. Infants have increased accommodative demands relative to adults (hyperopia) yet reduced vergence demands (narrow IPD) and therefore less effective coupling in the final motor response might be advantageous during development. Methods: This reasoning was tested by recording accommodation and vergence responses simultaneously from 74 3-4 month-old infants using an eccentric photorefractor (Multi Channel Systems, 25Hz). The infants were presented with an animated movie (a broadband spatial amplitude spectrum) moving repeatedly in a ramp fashion between dioptric distances of 1.1 and 2.85D. The subjects viewed the movie in full-cue binocular viewing conditions. The correlation between the accommodation and vergence responses to this stimulus was determined. Results: Sixty-six infants gave usable data and thirty-seven of them had a correlation between their accommodation and vergence data of greater than 0.6. The vergence responses were more repeatable within individuals than accommodation and relative drift of the accommodation response was not uncommon at levels (on the order of 1-2 D) beyond the depth of focus predicted by their expected acuity. Conclusions: These data suggest that while the accommodation and vergence systems demonstrate coupled responses during early infancy, the effective coupling in full-cue conditions is not complete. While this may lead to inaccurate responses at times, it could also permit young infants to maintain both focused and aligned visual experience during early development and reduce the potential for strabismus.

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42.26, *12:00 pm*

What can dots tell us about development of form and motion processing?

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The ventral and dorsal visual pathways that subserve form and motion processing have been hypothesized to have different developmental profiles (see Atkinson & Braddick, 2011). Using random dot kinematograms, we measured coherence sensitivities to three stimulus types: motion, static form and dynamic (i.e. flickering) form stimuli in typical development. Here, we asked whether sensitivity to coherent form and motion stimuli matures in a similar way. Moreover, since dynamic form stimuli have been described to induce illusory motion, we also asked whether sensitivities to dynamic form follow the development of sensitivities to static form or motion or something in between. We presented dots that moved coherently in a circle (motion stimuli) or formed a circular texture (form stimuli) to adults, 10-13 year olds, 8-9 year olds, 6-7 year olds, and 4-5 year olds. In a staircase procedure, we asked our participants to detect which of two intervals contained the circular movement or pattern. Motion coherence sensitivity showed a steeper increase than static or dynamic form sensitivity with age. Interestingly, 4-5 year olds showed the highest sensitivities to dynamic form stimuli and the lowest sensitivities to motion, suggesting that in young children dot motion and dot flicker are processed differently. In contradistinction, the sensitivities to motion and dynamic form were

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nearly identical in children 8 years or older. Together, our results suggest that the pattern of sensitivities to dot coherence is immature in children under the age of 7 years.

42.27, *12:15 pm*

Brightness local bias in children with autism spectrum disorder

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Autism spectrum disorder (ASD) has long been associated with a detail-oriented visual perception. Local-perceptual bias might be partially responsible also to the "core" deficits in the social domain, such as face processing and biological motion detection. There is a large literature describing this "local-perceptual bias" in ASD, which results, sometimes, in superior performances compared to typically developing (TD) children. However nothing is known about the lightness-perception (brightness) in children with ASD. We investigated the lightness-perception in 21 children, 11 TD and 10 children with ASD matched for age and IQ. Lightness-induction can occur on the basis of the immediate surround of a region (local interactions) and also on the basis of global factors of perceptual organization. We employed a stimulus set proved to differentiate the contributions of these two factors. In TD adults, according to the literature, when higher-level and lower-level factors act contemporaneously, the contrast effect induced by the global-organization principle of perceptual belongingness overcomes the local effect due to retinal lateral inhibition. In the Experiment 1, a grey scale matching task, the TD children confirmed the results obtained with adults: the brightness was a consequence of the global factors. On the contrary the children with ASD completely ignored the global information provided by the display. In the Experiment 2, we "simulate" the lightness-perception of the ASD children varying the time exposure of the stimulus in TD university students. The result was that the TD students' brightness was comparable to what observed in the children with ASD when visual stimulus was masked after 150 ms, suggesting that brightness processing in ASD is restricted to the low-level visual areas . In conclusion also the lightness perception in children with ASD is peculiar: a local bias affects their final percept and it could have consequences in their high-level social-communicative development.

42.28, *12:30 pm*

Visual development of contrast, orientation, and motion: comparison of VEP latencies

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The timing of VEP responses is a sensitive indicator of visual development. Past work has concentrated on responses to pattern reversal and to the latency of the initial positive peak. Here we compare the timing of VEP responses to pattern-, orientation-, and direction-reversal, and transient peak latencies to those calculated from the gradient of steady-state phase against reversal rate. The three stimuli were tested in 61 adults at 1- 16 r/s and 136 infants (age 3.6- 79.0 weeks) at 2- 8 r/s. Infants showed similar transient peak latencies for orientation and direction reversal, while adults showed similar pattern-reversal and orientation latencies. In both adults and infants calculated latencies for orientation and direction were significantly longer than the respective peak latencies. While transient latencies for the three stimuli converged around 20 weeks of age, calculated latencies of orientation and direction converged at 30 weeks. In summary, transient peak latencies of phase, orientation, and direction VEPs showed similar developmental trends suggesting possible parallel processing routes. Latencies calculated from steady-state phase, however, may reflect the timing of cortical feedback effects. While peak latency indicated that initial detection of motion matured before orientation, calculated latency revealed that the fine-tuning of orientation matured before motion processes.

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Monday Morning Posters

Scene perception: Categorization

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

43.301 Measuring the temporal order of feature processing in natural scene categorization

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Humans can quickly and reliably recognize natural scenes as members of particular categories (Potter 1975). Several features have been proposed to underlie this ability, e.g., the amplitude spectrum of spatial frequencies (Oliva and Torralba 2001); color (Oliva and Schyns 2000); integrity of the phase spectrum (Sadr and Sinha 2001); or scene structure represented by line drawings (Walther et al. 2011). How can we reconcile these different claims? Presumably, the brain uses all of these features when they are available. However, the timing of feature utilization likely depends on where in the visual processing hierarchy particular features are processed. Here we introduce a new method that allows us to measure the time order of features in their contribution to natural scene categorization. Participants were trained to categorize briefly presented, masked images of natural scenes from six different categories in a six-alternative forced-choice (6AFC) task. After staircasing stimulus onset asynchrony (SOA) to a performance level of 65% (chance: 16.7%), SOA was held constant for the remainder of the experiment. In test trials, the SOA was split in half, and during each half, a different version of the same natural scene was presented. The two versions consisted of two different feature representations, e.g., a line drawing and a color photograph. The order of the two versions was randomized and counter-balanced across categories. We expect accuracy in the 6AFC task to be higher when the versions are shown in the same order in which they are processed in the brain compared to presentation in the reverse order. In a validation of this method we found, for instance, that the color and texture information contained in color photographs were processed earlier than the structure information conveyed by line drawings ($p<0.01$), which is consistent with known neurophysiology of the human visual system.

43.302 Global, but not focused attention impairs the ultra-rapid categorization of natural scenes

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It takes less than 150 ms for the primate visual system to categorize a complex scene (Thorpe et al., 1996). Although such ultra-rapid categorization (URC) is fast and efficient, there is considerable debate regarding the mechanism that accounts for the process. The URC mechanism has been argued to operate rapidly outside of the focus of attention; yet, and in contrast, it has been demonstrated that scene classification is impaired when attention is allocated to a concurrent task (Walker et. al, 2008). Here, we address this apparent contradiction by examining which mode of attention (focused or global) is most compatible with the URC mechanism. Observers performed a Go/No-Go task in which they were asked to indicate whether or not a briefly presented natural image (32 ms) corresponded to a cued category. On some trials, observers completed a concurrent attentionally demanding task that required either global attention (indicate the orientation of a large box bordering the image) or focused attention (indicate the orientation of a small box located in the center of the image; cf. Chong & Treisman, 2005); in a control condition there was no attention task. Blocks were separated by unique cue / distractor pairings, allowing for the use of signal detection analysis to determine sensitivity and bias parameters between specific categories. Results indicated that categorization performance was worse when observers were asked to complete a concurrent attentionally demanding task than when they were not, corroborating previous data suggesting that attention affects the URC mechanism. Further elucidating these effects, results also indicated that categorization performance was higher when observers completed a concurrent focused attention task than a concurrent global attention task, suggesting that the URC mechanism is most affected by concurrent tasks that require global attention, and that this impairment is reduced when the categorization task requires focused attention.

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43.303 The role of attention in the perception of good and bad exemplars of natural scene categories

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Images of natural scenes are quickly and accurately categorized by human observers, even under conditions of limited attention (Li et al., 2002). Recent work has shown that images rated as highly representative of their category ("good" exemplars) are categorized more accurately by human observers compared to less representative images ("bad" exemplars; Torralbo et al. 2009). Here, we investigated the role of attention on the perception of good and bad natural scene category exemplars. In order to study scene perception under conditions of limited attention, we used statistical pattern recognition algorithms to "decode" scene category from fMRI data when observers' attention was directed toward scenes or a separate task at fixation. This technique has previously been used to show that scene category information is present in scene-selective cortical areas (Walther et al., 2009), and that "good" category exemplars can be decoded more accurately than "bad" ones (Torralbo et al, 2009). On separate runs, participants alternated between searching for predefined color-shape conjunction targets within a stream of small colored crosses superimposed at fixation on a stream natural scenes and detecting repetitions in the stream of scene images themselves. Because the displays were identical in both conditions, this allowed us to measure the influence of observers' attentional focus on scene category decoding accuracy. Our results again showed that decoding accuracy was higher for "good" than "bad" category exemplars. Additionally, we found that scene category decoding accuracy was higher when the task required participants to direct their attention to the scenes, though it remained above chance during the fixation task. However, when attention was directed away from scenes, the difference between "good" and "bad" exemplars was absent. This result indicates that the advantage for good natural scene category exemplars is influenced by the locus of visual attention.

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43.304 A large-scale taxonomy of real-world scenes

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Scene classification is critical to human scene understanding. The scientific study of scene perception requires a shared vocabulary and taxonomic organization of scene categories. What classes of scenes are there? The only attempt at building a cognitive scene taxonomy comes from a small study using eight categories (Tversky & Hemenway, 1983). Here, we endeavor to fill this knowledge gap by creating a more comprehensive taxonomy of scene categories using a large set of image categories that better approximates the richness of the real world. Experiment 1 examined 100 studies in visual cognition and computer vision that listed "scene categorization" or "scene classification" as keywords. We tabulated the categories examined in each study, finding a total of 1195 unique category names. Category occurrence roughly followed a power law: many categories occurred in only one study (n=418) while few categories (n=20) were found in at least 10% of studies. The 1195 categories vary in their level of abstraction and represent a highly diverse set of entities, ranging from proper nouns, events, objects, animals and people. How are these scene categories organized in a conceptual space that reflects human cognition and perception? Experiment 2 examined these questions via a large-scale online categorization experiment. We amassed a database of 1055 putative scene categories taken from Experiment 1. Participants viewed pairs of images that were either drawn from either the same or different categories, then indicated whether they would place them in the same category. Results indicate only a small number of scene categories have high participant agreement (~2%). Hierarchical clustering reveals multiple levels of class similarity. Altogether, we pro-

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vide the first large-scale attempt at a full taxonomy of real-world scenes, a critical step for furthering the study of human scene representation and organization.

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43.305 Learning perceptual relations for categorizing natural scenes from few training examples

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The ability to categorize visual scenes rapidly and accurately is highly constructive for both biological and machine vision. Following the seminal demonstrations of the ability of humans to recognize scenes in a fraction of a second (e.g.,Potter and Levi,1969; Biederman, 1972), much research has been devoted to understanding its underlying visual process (e.g., Thorpe etal., 1996; Oliva and Torralba, 2001; Loschky and Larson, 2008, 2010), as well as its computational modeling (e.g., FeiFei and Perona, 2005; Lazebnik etal., 2006; Xiao etal., 2010). In this work we focus on one aspect of the scene categorization process and investigate whether prior knowledge about the perceptual relations between the different scene categories may help facilitate better, more efficient, and faster scene categorization. We first introduce a psychophysical paradigm that probes human scene categorization, and extracts perceptual relations between scene categories. Then, we show that these perceptual relations do not always conform the semantic structure between categories. Finally, we incorporate the obtained perceptual relations into a computational classification scheme, which takes inter-class relationships into account to obtain better scene categorization, particularly when supervised categories are under-sampled. We argue that prior knowledge of such relationships could partly explain the fact that humans are often able to learn and process scene categories from very few training examples, while computational models usually need at least tens of training examples per-category before achieving reasonable categorization performance.

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43.306 Beyond Gist: Diagnostic Information Changes with Level of Scene Categorization

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Being able to categorize our external visual environment is a critical preliminary step for interacting with the world. How we categorize our environment affects subsequent behaviors: e.g., categorizing a scene as a library would suggest proper social etiquette, location of task-relevant objects, etc. Because of the speed with which a scene can be processed, gist processing – that is, what can be discerned within a single glance – has been a frequent topic of research that has promoted a feed-forward processing mechanism. However, categorization can extend beyond gist: scenes can be categorized at different hierarchical levels of specificity; the same scene can be categorized at the superordinate (e.g., indoors), basic (restaurant) and subordinate (diner) level. In our study, we ran two experiments in order to elucidate a top-down component of scene categorization. Participants were asked to categorize scenes at either the basic or subordinate level as a function of low-pass filtering. Basic level categorizations reached an above chance level of performance at a lower-filtering level than subordinate judgments, indicating that diagnostic information changes as a function of the level of category specificity. In a second experiment, scenes were low-pass filtered to a level where the basic level gist of a scene was recognizable but accuracy in determining the subordinate level category was at chance, while a gaze-contingent window showed full resolution information to the fovea. By summing fixations made when making either basic or subordinate judgments, we recorded what high-spatial frequency information participants needed in addition to the low-pass information in order to make accurate judgments. The results showed that the scene regions considered diagnostic changed with the level of category specificity. This suggests that there is a bi-directional interplay between available image features and task-constraints when determining a scene's category.

43.307 Fixation patterns predict scene category

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The ability of humans to quickly and efficiently categorize natural scenes is often referred to as fast "gist" recognition, which then affects subsequent, more detailed analysis of the scene. However, little work has been done to demonstrate the influence of scene category on later stages of processing. Here we test how scene category affects eye movements in an exploration task. Participants freely viewed 198 color photographs of natural scenes from six categories (beaches, city streets, forests, highways, mountains, and offices) for two to eight seconds, while their eye movements were recorded. We then attempted to predict scene category based on the pattern of eye movements on a trial-by-trial basis using a procedure similar to the normalized scanpath salience by Peters et al. (2005) with fixation density maps (FDM) derived from training data. We could predict scene category correctly for 33.4% of the trials in the test data (chance: 16.7%). The category-specificity of the fixated locations may stem from two sources: consistent patterns of salience determined by scene layout or other, more abstract biases based on the category label. To test the influence of salience we repeated the analysis, but using the average salience maps (Walther and Koch 2006) for a given category for training instead of FDMs. In this analysis we could predict scene category with 22.3% accuracy. In a follow-up experiment we restricted visibility of the image to the central 7 degrees of visual angle (2.4% of the image area) around the current eye position, thereby suppressing global scene processing. Trials were blocked by scene categories in order to enhance category-based biases. Accuracy of predicting scene category was 23.0% in this condition. These results suggest that both shared patterns of salience and more abstract category-based information contribute to category-specificity of fixations.

43.308 Exploring the contents of the category-specific attentional search template

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Humans are extremely efficient at detecting object categories in briefly presented photographs of natural scenes. Recent work investigating the neural mechanisms underlying this ability (Peelen et al., 2009; 2011) found that response patterns in object-selective visual cortex carried information for the relevant but not for the irrelevant category. This suggests that rapid category detection in natural scenes is supported by an attentional search template that pre-activates category-specific neurons, enabling efficient target processing. In the current study we aimed to investigate the contents of this template using a subliminal priming paradigm. We reasoned that, if a subliminally presented stimulus facilitates target detection this may be indicative of overlap between the representation of the prime and the attentional search template. Participants viewed centrally presented monochromatic photographs of natural scenes containing (1) people, (2) cars, (3) cars and people or (4) no category. On separate runs, participants were instructed to detect either cars or people. Scenes were preceded by a black and white random noise mask that was presented for 200ms. A prime was shown on two thirds of the trials for 35ms following the mask. The prime depicted one of four exemplars of either a car or a person. Invisibility of the primes was confirmed for each subject in a second experiment that required categorization of the primes. In the main experiment target detection was significantly faster for scenes preceded by a prime matching the target category compared to scenes preceded by a non-matching prime. Simple prime-response associations cannot account for this detection advantage as the prime condition did not differentially affect reaction times for target-absent scenes, thus suggesting overlap between the representation of the employed primes and the attentional search template. In future work systematic variation of the primes will allow for more detailed characterization of the search template's content.

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43.309 Probabilistic, ultra-sparse, structural representations of natural scene categories

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Monday AM

Humans can grasp the gist of complex natural scenes very quickly and can remember extraordinarily rich details in thousands of scenes viewed for a very brief period. This amazing ability of rapid scene perception challenges both the traditional view of image-based, bottom-up visual processing and more recent models of scene categorization based on global visual features and features at low spatial frequency. We developed ultra-sparse structural representations of natural scenes using natural scene structures as encoding units. Each natural scene structure is a spatial concatenation of a set of structured patches in natural scenes and each structured scene patch is a concatenation of independent components of natural scenes. Natural scene structures convey various amount of information about scene identities and categories since general structures are shared by more scenes while specific structures are shared by only a few scenes. Thus, any natural scene and category can be represented by a probability distribution based on a set of natural scene structures and their spatial concatenations. These structural representations require no isolation of objects or figure-background segmentation, nor computation of global scene features. We tested this model of rapid scene categorization. We compiled a set of informative natural scene structures for each scene category and then, from a set of natural scenes, constructed experimental stimuli that consisted of only the selected natural scene structures. We either maintained or shuffled the spatial locations of the natural scene structures in the original scenes. We found that the subjects' categorization performance was significantly above chance even when the selected scene structures covered only a few percent of the area of the scenes. Furthermore, shuffling the spatial locations of the scene structures significantly reduced the subjects' performance. These results support our model of probabilistic, ultra-sparse, structural representations of natural scene categories.

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43.310 Scene Understanding for the Visually Impaired Using Visual Sonification by Visual Feature Analysis and Auditory Signatures

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The World Health Organization estimates that approximately 2.6% of the human population is visually impaired, with 0.6% being totally blind. In this research we propose to use visual sonification as a means to assist the visually impaired. Visual sonification is the process of transforming visual data into sounds - a process which would non-invasively allow blind persons to distinguish different objects in their surroundings using their sense of hearing. The approach, while non-invasive, creates a number of research challenges. Foremost, the ear is a much lower bandwidth interface than the optical nerves or a cortical interface (roughly 150k bps vs. 10M bps). Rather than converting visual inputs into a list of object labels (e.g., "car", "phone") as traditional visual aids systems do, we conjecture a paradigm where visual abstractions are directly transformed into auditory signatures. These signatures provide a rich characterization of object in the surroundings and can be efficiently transmitted to the user. This process leverages users' capabilities to learn and adapt to the auditory signatures over time. In this study we propose to obtain visual abstractions by using a popular representation in computer vision called bag-of-visual-words (BoW). In a BoW representation, an object category is modeled as a histogram of epitomic features (or visual words) that appear in the image and are created during an a-priori off-line learning phase. The histogram is than directly converted into an audio signature using a suitable modulation scheme. Our experiments demonstrate that humans are capable of successfully discriminating audio signatures associated to different visual categories (e.g., cars, phones) or object properties (front view, side view, far) following a short training procedure. Critically, our study shows that there exists a tradeoff between the complexity of representation (number of visual words used to form the histogram) and classification accuracy by humans.

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Object recognition: Categories

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

43.317 Representations of Difficulty and Confidence in Numerical Discrimination

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Optimal decision making requires both perceptual evidence and an estimation of the reliability of such evidence. Importantly, judgment difficulty and confidence (the subjective sense of the likelihood of success) may be separate components of an overall sense of reliability. In the present experiment, we investigated how observers represent discrimination difficulty in the context of numerical discrimination judgments. In our first experiment, we presented participants with a display of blue and yellow dots that varied in ratio and, hence, discrimination difficulty (e.g., discriminating 20:4 dots is easier than 20:9 dots while both decision are highly accurate). Participants had to click on a line to indicate how difficult they thought the trial was. We found that participants had representations of difficulty that were not merely based on the confidence or response time of their decision – even with discrimination performance at 100%, participants continued to reliably discriminate one easy trial from an even easier one. Given this differentiation, we sought to characterize the psychophysical signatures of difficulty representations (e.g., the precision, the relationship of variance to the mean, etc.). In the second experiment, participants were shown two trials of blue and yellow dots, and had to judge whether the first or second trial was easier. We found that observers' judgment of difficulty obeys Weber's law and scalar variability: the ability to successfully determine the easier trial depends on the magnitude of the difference between the ratios, suggesting that representations of task difficulty are continuous and probabilistic in format. Furthermore, we measured and established the internal noise associated with difficulty representations, and found them to be close and correlated, but not exactly equivalent, to the noise associated with representations of number used in the task. We discuss these results in the context of theories of decision making, confidence, and optimal behavior.

43.318 Coding object size based rules in 3D visual scenes

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Learning abstract rules in the auditory and visual domains is customarily investigated with the AAB vs. ABB paradigm where each scene contains three auditory events or visual objects and either identity or an attribute of these items, such as the size of the objects, follows a "same-same-different" (i.e. AAB) pattern during a training period. In a subsequent test session, never seen before items are used and subjects' preference to judge the AAB over ABB arrangements as familiar is taken as evidence for acquiring the abstract rule. We asked whether 2D retinal or 3D perceptual size is the basis of this judgment in case of visual rule learning of size arrangements. We used three triplets of 3D computer graphic colored objects arranged in perspective so that by physical extent on the screen they followed a large-large-small (AAb) template, but due to perspective their perceptual appearance was (aBB). After 2 minutes of random sequential presentation of the triplets for 2 sec each without any explicit task, two tests were administered with two versions of instruction. In the first test (No Context), context and perspective were taken away, and triplets were presented horizontally on white background, in the second (Context), exactly the same context was used as during the practice. The instructions were either "choose the more familiar scene" (Naïve) or "considering size, chose the more familiar scene" (Cued). In the Naïve-No Context condition, subject showed no preference between AAb and aBB, which changed in the Cued condition to significant aBB preference. In the Cued-Context condition, subjects showed a strong aBB preference. However, in the Naïve-Context condition, they switched to significant AAb preference. Thus size-rule coding seems to utilize high-level perceptual coding of size when directed explicitly, but in implicit familiarity tasks the more veridical retinal coding has a stronger influence.

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43.319 The role of low-level features for rapid object detection and guidance of gaze in natural scenes

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Humans detect objects in complex scenes at remarkable speed with little attentional effort. Do the mechanisms that underlie such rapid processing also guide attention and gaze during prolonged viewing, which operates on a much longer time scale? Low-level features, like luminance contrast, affect object detection in rapid-serial-visual-presentation (RSVP) paradigms and have some predictive power for gaze allocation, which is, however, explained away by objects. To test whether features similarly affect gaze and detection, we used the same stimuli in two tasks: prolonged viewing and RSVP. Stimuli consisted of natural images, in which the luminance contrast of an object and of its background were independently manipulated. In prolonged viewing, eye positions were recorded during 3 seconds of presentation, afterwards observers were queried for keywords describing the scene. In RSVP, observers had to detect the presence of a target object in a 1-second stream of 20 images presented at 20 Hz, and detection performance was measured. By comparing the changes in behavior relative to a neutral condition (i.e., the unmanipulated image) in both tasks, we show that gaze control and object detection, although very different tasks, are affected similarly by changes in a low-level feature; luminance contrast. Further experiments reveal that the pattern of results depends on the image manipulations being targeted at an object in the scene, and is independent of the presence of distractor objects. Although gaze is guided by luminance-contrast increases of objects, this does not change how characteristic the objects are perceived to be for the scene. These results imply that scene content interacts with low-level features to guide both detection and overt attention (gaze), while certain aspects of higher-level scene perception are not affected by the same low-level features.

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43.320 Creating domains of perceptual processing through category learning

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Category learning research typically teaches participants categories, with no consequence for how items on each side of the boundary should be treated. In real life, however, we learn categories that predict further processing goals, which can influence perceptual strategies. Using methods from category learning and perceptual expertise, we studied how people can learn object categories with different perceptual goals within the same feature space. In Experiment 1, participants first learned to categorize a two-dimensional morphspace of complex novel objects into two categories and then learned a different perceptual task, either individuation or local feature judgment, for each category. Later, participants were shown objects from both categories together and had to perform the category-appropriate task for each one. A same-different discrimination test before training and after each training phase measured changes in sensitivity to feature dimensions of the space. After categorization, we found the expected increase in sensitivity along the category-diagnostic dimension. After category-task training there was an increase in sensitivity on both sides of the space for both the category-diagnostic and category-non-diagnostic dimensions although there was evidence that some changes were not global but were applied more locally within the space. In Experiment 2, the same design was used with added emphasis on speeded responses during the category-task training to make categorization-for-perception more automatic. We found the same improvement along the category-diagnostic dimension after categorization and similar patterns of stretching in the feature space in both dimensions after category-task training. We also saw preliminary evidence of greater holistic processing for objects on the side of the space that participants learned to individuate. The results demonstrate the feasibility of studying a more ecological flavor of category learning in the laboratory, to provide a useful model of how continuous perceptual spaces could be carved into distinct domains where objects are perceived differently.

43.321 Presentation time does not affect superordinate-level advantage in ultra-rapid categorization

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A recent study (Mace et al., 2009) challenged the prevalent idea of a basic-level advantage in categorization. They showed that the processing time required to access basic visual categories (such as a dog) is longer than that needed to access superordinate visual categories (such as an animal). Mack & Palmeri (2011), among others, argue that these results can be explained as a consequence of the brief stimulus presentation time (25ms) used in the Mace et al. study. Visual information gathered from such fast presentations could be minimal, degraded, and emphasize coarse visual information. In this study, we tested whether the superordinate-level advantage (SLA) found with briefly flashed images could be reproduced with longer stimulus presentation times. Participants were asked to perform a go/no-go visual categorization task at either the superordinate (animal/non-animal) or the basic (bird/non-bird animal) level. Images were presented for 25ms, 250ms or 500ms. Reaction times were faster for superordinate-level categorization than for basic-level categorization at all presentation durations (SLA at 25ms = 55±10ms; 250ms = 34±4ms; 500ms = 37±6ms; one-way repeated measures ANOVA: $F(2,24) = 2.43$; $p>0.1$). The same SLA was also found when a yes/no response was required instead of a go/no-go (presentation time 250ms; SLA for yes/no = 29±10ms; go/no-go = 32±6ms; paired t-test: $t(8)=0.22$, $p>0.8$). Our results clearly show that the superordinate category is accessed faster than the basic category, regardless of the presentation time or the type of response. Thus, presentation time cannot explain the basic-level advantage found in other studies. However, other factors, such as the kind of stimuli (isolated animal or animal in a natural scene), the kind of task (naming or detection), might be involved. These possibilities must be tested in further experiments.

43.322 The contribution of general object recognition abilities to face recognition

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Theories of face perception and recognition are often tested in studies contrasting performance with faces to that with other objects. Tasks that compare faces to a single object category cannot attribute the difference to faces as being unique and cannot reveal differences between non-face categories. We introduce a test of object recognition, the Vanderbilt Expertise Test (VET), with the goals of measuring general object recognition ability and providing a valid measure of domain-specific performance that may reflect expertise. The VET is modeled after the Cambridge Face Memory Task (CFMT; Duchaine & Nakayama, 2006) and measures the ability to recognize visually similar exemplars from eight categories of real-world objects (blocked). In Experiment 1, 223 participants completed the VET. Principal components analysis (PCA) revealed that the categories form coherent subsets that are relatively independent of one another. Performance with leaves, owls, butterflies, wading birds, and mushrooms loaded on Factor 1 (47.8% variance), whereas cars, planes, and motorcycles loaded on Factor 2 (13.9% variance). An analysis of individual factor scores revealed an effect of participant sex: females had higher scores for Factor 1 than 2, whereas males showed the opposite pattern. In Experiment 2 (N = 26), we found evidence for convergent validity of the VET as a measure of domain-specific expertise by comparing the VET to a perceptual matching indicator used in prior work to measure domain-specific expertise. Specifically, perceptual expertise for cars and planes selectively predicted performance in the VET for cars and planes, respectively. In Experiment 3 (N = 66), the VET was used to show that object recognition abilities contribute to face recognition performance, independently of age and holistic processing. Together, our results highlight the importance of considering multiple object categories when studying individual differences and demonstrate an independent contribution of general object recognition abilities to face recognition.

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43.323 Uncovering the time course of categorization with object-substitution masking

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Visual object categorization maps visual representations onto category names. It is a process that takes time with some categorizations taking more time than others. The classic finding of a basic-level ("dog") advantage in categorization (Rosch et al., 1976) has been challenged by the finding of a superordinate-level ("animal") advantage during ultra-rapid categorization (Macé et al., 2009). Recent work attempting to reconcile these findings (Mack & Palmeri, 2011a, 2011b) proposes that weak perceptual evidence of an object's superordinate category is available early in the time course of categorization. The current study investigated this proposal by uncovering critical points in the latent time course of categorization with an object-substitution masking (OSM) paradigm (Di Lollo et al., 2000). The extent of an OSM effect on categorization indicates not only the nature of categorization processes, but also when these processes occur. Participants performed category verification of superordinate (animal vs. vehicle) and basic (dog vs. bird, car vs. plane) target objects among two object distractors. An OSM mask consisting of four black squares surrounded the target object and vanished after the brief presentation of the stimuli or after a 50ms delay. Basic-level categorization was significantly impaired with the mask delay, while superordinate categorization performance was relatively spared. A parametric manipulation of mask delay (0-125ms) showed further evidence of temporal differences between superordinate and basic-level categorization. While a masking effect was evident in both conditions, superordinate categorization was impaired with a shorter mask delay (25ms) than basic-level categorization (33ms). This novel use of object-substitution masking suggests that categorization of real-world objects may depend on iterative sampling of visual information. The timing of the OSM effects reveals the latent time course of visual object categorization: perceptual evidence for the animal in a scene is available quickly and faster than evidence for the bird.

43.324 Auditory Scene context, visual object identification, and spatial frequency

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How do we use cross-modal cues to accurately identify the objects and scenes we see and hear? Furthermore, how do the different sensory processes influence each other in these identification processes? Participants were presented with auditory contexts for 5 s before a target object was briefly presented. Observers then identified both the auditory scene and the visual object. The aforementioned questions were examined with objects presented in high and low spatial frequency, in either congruent, incongruent, or neutral (white noise) contextual relations. Additionally, two levels of object and contextual constraints, defined in a pilot study, were examined. Auditory scenes and visual objects more easily (i.e., more accurately) identified were categorized as a "strong" stimuli and were paired with each other. Less accurately identified auditory scenes were paired with less accurately identified visual objects and were categorized as "weak" (ambiguous) stimuli. First results concern object identification. When paired with a strong auditory context, congruently paired objects were more accurately identified than both incongruent and neutral contexts. These results were similar across spatial frequency. With weak contexts, the question was, could two weak sources of information (e.g., scene and object) combine to facilitate identification? The data suggests that such effects were not present. In the main experiment, with additional experiments for power, there were no advantages for congruent contexts over incongruent or neutral contexts. However, there was an unexpected main effect of spatial frequency for these "weak" stimuli: high spatial frequency objects were better identified across all contextual relational conditions. These results are in contrast to the strong constraint stimuli. There was a small reciprocal effect for auditory scene identification. Congruent auditory scenes were somewhat better identified than incongruent conditions. These results provide new information about the detailed interactions between sources of information in multimodal identification.

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43.325 Dissociating contextual and semantic priming in object recognition

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Object recognition is thought to draw on associations stored in memory. While the influence of semantic associations (e.g., dog-cat) is widely documented, the importance of contextual associations is not well understood. In fact, contextual associative effects have only been demonstrated with an entire scene as a contextual prime for individual target objects. Here we explore whether individual objects in isolation are sufficient for activating contextual associations that facilitate the recognition of other contextually related objects by dissociating the potential influences of contextual and semantic associations among objects on recognition. In an object priming task, we defined contextually related prime-target pairs as objects that often co-occur in the same environment but do not belong to the same category (e.g., penguin-iceberg), whereas semantically related objects belong to the same basic-level category but do not typically co-occur in the same environment (e.g., penguin-flamingo). We also included conditions with objects related both contextually and semantically (e.g., penguin-seal), unrelated objects (e.g., penguin-bicycle), and objects paired with nonsense objects. Participants (n=24) judged if the target was an actual or nonsense object. Compared with the unrelated baseline, all three related conditions showed significant priming (approximately 30ms faster for related than unrelated objects, $p<.05$), regardless of the interval between the prime and target objects (100ms-1000ms). The contextual and semantic priming effects were found to be equivalent in strength, which shows that multiple sources of object knowledge influence recognition. Importantly, this is the first demonstration of a robust contextual facilitation triggered by an individual object. This finding supports theories in which recognition is proposed to be a proactive process, whereby our visual system is constantly making predictions and inferences about plausible interpretations based on the objects that have already been recognized.

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43.326 Visual and Semantic Contributions to Object Perception

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The perception of common objects elicits both visual and semantic information. We investigated the contribution of these two sources of information to object processing in a paradigm in which these sources were independently manipulated. Experimental stimuli consisted of pictorial object pairs that shared either visual or semantic features (e.g., visual: BLIMP/SHARK; semantic: GUITAR/TRUMPET). Visual and semantic similarity were independent, with visually matched items coming from distinct semantic categories and semantically matched items sharing few perceptual features. Objects were presented in pairs, with one object serving as a prime for the second target object. In two behavioral experiments, subjects either verbally named the target or responded "match/non-match" to a word label presented following the target display. Behavioral priming effects in both the picture-naming and label-matching tasks were calculated to compare the impact of similarity in the visual versus semantic conditions, relative to a neutral control condition. Results were consistent across task modality, with both tasks yielding negative priming effects in the visually congruent condition (e.g., correctly saying "shark" or correctly responding that the label "SHARK" matched when a BLIMP prime was followed by a SHARK target). Thus, sequentially viewing pictorial stimuli with a high degree of visual feature overlap led to task interference. Interestingly, these results differ from previous findings of positive priming for perceptually matched word pairs (Schreuder et al., 1984). We interpret our negative priming effect as interference stemming from activation of multiple associated labels upon viewing pictures of the objects. Since both tasks required responses at the semantic level, the presence of shared visual features in the absence of the typical semantic co-occurrence lead to interference. These findings indicate that insofar as category labels and their associated semantics impact visual object processing, these effects may actually be more significant than the perceptual similarities that arise between visual objects.

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43.327 **Equally invisible but neurally unequal: Cortical responses to invisible objects differ as a function of presentation method**

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Visual stimuli presented without any corresponding visual experience may still lead to neural processing (Moutoussis & Zeki, 2002). Understanding the stimulus-processing capabilities of the brain under these circumstances is a key goal of psychological research. It is unknown whether unconscious processing differs depending on the method used to prevent stimuli from entering awareness. We asked whether two methods for rendering stimuli invisible (chromatic flicker fusion and continuous flash suppression) had different effects on object processing within the human brain. Using functional magnetic resonance imaging (fMRI) we presented subjects (N=15, 9 males) with face and tool stimuli that were either fully visible or rendered invisible using one or the other method. Whole-brain decoding and multivariate searchlight decoding showed that both category and, surprisingly, subcategory-level information was present when stimuli were invisible as well as visible. However, the cortical and subcortical response pattern differed as a function of stimulation method. Visible category and subcategory decoding primarily relied on dorsal cortical (frontoparietal) and subcortical (superior colliculus, thalamus) attentional regions and ventral cortical (occipitotemporal) perceptual regions. Chromatic flicker fusion permitted decoding within cortical and subcortical areas, including prefrontal and striatal regions, that were largely nonoverlapping with regions that permitted decoding stimulus category and subcategory during continuous flash suppression, which primarily relied on parietal and occipitotemporal regions. In conclusion, category- and subcategory-level information is available even when stimuli do not enter awareness, and the availability of this information across the whole brain depends critically on the method used to render stimuli invisible. These results have implications for studying the neural correlates of consciousness, suggesting that some fine-grained subcategory-level information is available in the absence of awareness. Furthermore, they indicate that the suppression method used to study object processing in the absence of awareness should be tailored to the specific mechanisms or brain regions being studied.

43.328 **A test of the embodied simulation theory of object perception: Motor simulations in response to artifacts and animals**

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Orientation decisions about upright and inverted manipulable objects are faster when their handles are presented in the visual field that corresponds to the response hand (Tucker and Ellis, 1998). This compatibility effect is interpreted as the covert simulation of a motor program in response to the visual presentation of a manipulable object. Further, this finding is often cited as direct evidence of embodied representations of objects. Critically, if this interpretation is correct, then such effects should not extend to a category of objects for which we have no motor experience. In the present set of experiments, participants made orientation decisions about photos of manipulable objects and animals presented in either upright or inverted orientations and responded with either their left or right hands. The objects' handles or the animals' tails pointed left or right. Across two experiments, compatibility effects for artifacts depended on the absolute size of the object. That is, compatibility effects were observed for large but not small images. In a third experiment, we manipulated the perceived size of objects by using large or small pictures of hands as primes. Compatibility effects were shown regardless of perceived size, further suggesting that absolute size is important. Importantly, contrary to predictions, a reverse compatibility effect for natural objects was found that also depended on absolute size. Finally, in a fourth experiment, a compatibility effect for artifacts depended on the task. Specifically, when the task was conceptual (categorization) and did not stress the manipulable aspects of the object, the compatibility effect reversed for artifacts. These results challenge the frequent interpretation of previous compatibility effects as resulting from embodied simulations and suggest a more general stimulus-compatibility effect.

43.329 **Testing within-category exemplar discriminability in pattern-information analysis**

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In the last few years, fMRI studies of visual object representations have begun to probe within-category exemplar distinctions. Most of them defined an exemplar discriminability index (EDI) as the difference between the average of the pattern distances between different exemplars (i.e. the effect) and the average of the pattern distances for repetitions of identical exemplars (i.e. the noise). (Note that for the popular correlation distance (1-r), the difference of distances is equal to the difference of correlations: (1-r1)-(1-r2)=r2-r1.) The EDI's significance is then commonly assessed using a t-test (H0: group-average EDI = 0) across subjects. This approach is valid under the assumption that the EDI is 0-mean normal under H0. However, the EDI is a difference of two non-normal variables with different variance, and thus not in general 0-mean or normal. Here we address whether t-testing EDIs still provides acceptable protection against false positives in practice, and explore alternative tests. In simulations, we explore a wide parameter space for data and analysis (number of voxels, number of conditions, regional-mean activation level, pattern modulation across voxels, distance measure, pattern normalisation), and show that the EDI is usually nearly 0-mean normal under H0 (although the theoretically expected violations do occur). This means that the previous results are probably trustworthy. We describe and validate alternative tests of the EDI that use randomisation and do not require EDI normality. Moreover, these tests allow single-subject and group analysis (with subject as a fixed or random effect). Application to simulated and real fMRI data suggests that these non-parametric tests have similar power as the t-test approach. These methods may enable vision scientists to safely and sensitively detect subtle pattern differences including subordinate distinctions.

43.330 **Re-thinking the functional organization of human visual cortex**

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Visual cortex consists of low-level regions containing systematic representations of the visual field (e.g. retinotopic maps), as well as high-level regions specialized for processing complex shapes such as faces and limbs (e.g. the fusiform face area and extrastriate body area, respectively). Prevailing views adopt dichotomous organization principles for low- and high-level functional regions and associated neural computations, where the former are thought to be systematically organized and the latter less systematic and highly variable - both anatomically, as well as relative to other high-level visual areas. Using higher-resolution (1.5mm voxels) fMRI scanning methods than past studies (3-5mm voxels), we recently conducted a series of experiments (Weiner & Grill-Spector, 2010, 2011a,b) revealing that the spatial location of high-level visual regions selective for faces and limbs are much more consistent than once thought. Furthermore, these experiments reveal a topographic organization of face- and limb-selective regions extending from lateral occipitotemporal to ventral temporal cortex where each high-level region is defined by a combination of anatomical and functional boundaries separating them from neighboring regions. The anatomical and functional boundaries of this high-level topographic map are reliable across subjects and longitudinally within-subjects over a span of three years. Here, we propose a multi-factor parcellation framework resulting from our empirical measurements using the following criteria: 1) precise anatomical location of functional regions, 2) preserved spatial relationship among functional regions, 3) preserved relationship relative to known visual field maps, and 4) reliable functional differences among regions. The implementation of this framework allows the first consistent parcellation of high-level visual regions outside of visual field maps. Moreover, it illustrates that defining brain areas from one measurement of category selectivity is insufficient. Though we use high-level visual cortex as a model system, this framework can also be applied to other sensory and potentially nonsensory cortical systems.

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43.331 **The Neural Correlates of Feedback Information Processing in Visual Category Learning Tasks**

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Recent fMRI studies show that Visual Category Learning (VCL) is supported by multiple neural systems in the human brain which are presumably required for handling the wide range of demands involved in different VCL tasks. In the current study we scanned 14 healthy young adult and contrasted between their brain activities in supervised VCL tasks (with informative trial-by-trial feedback) and unsupervised VCL tasks (no feedback). For each task we used distinct novel creature-like stimuli that differed from one another across several feature-dimensions (e.g. body shape, limbs size, tail length…), but only one feature-dimension was important for determining the category membership to one of two subcategories. This design mimics the ambiguity one experiences when introduced with novel objects which can be classified in different ways. In each trial participants viewed two sequentially presented creatures and were asked to determine if they belong to the same category or not. Each learning trial was composed of three sequential events – stimuli presentation, response via key press and feedback. This enabled disassociating the neural correlates of these VCL components. We examined which cortical regions were associated with processing the feedback information using individual subject analyses. Our data show a network of brain areas that exhibit higher responses only when a participant was making an error and when informative feedback was provided. This includes the anterior cingulate, bilateral frontopolar and ventrolateral cortices (13/14 subjects), intraparietal sulcus (11/14) and cerebellum (12/14). In only about half of the participants we saw similarly higher activity associated with error trials in the ventral occipito-temporal cortex (7/14) and the caudate nucleus (8/14). This suggests that neural systems involved in error detection and conflict management (anterior cingulate), cognitive control (frontopolar; ventrolateral), visuospatial processing (intraparietal sulcus) and response learning (cerebellum) are the most critical for supporting VCL tasks by processing negative feedback.

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43.332 **Effect of Target/Non-Target Similarity on the Timecourse of Visual Object Recognition: An ERP investigation**

Amy Guthormsen[1](aguthorm@lanl.gov), Michael Ham[1], Brenna Fearey[1], Luis Bettencourt[1], John George[1]; [1]Los Alamos National Laboratory

Some have argued that, because visual object recognition occurs so fast (<150 ms.), it must be essentially a feed-forward system. A study commonly cited as support reveals divergence between brain responses to visual targets and those to non-targets occurring around 150 ms after stimulus onset (Thorpe et al. 1996). However, it has been argued that visual targets (animals) differed in systematic ways from the non-targets (natural scenes with no animal). In this study, we investigated the effect of target /non-target similarity on the timecourse of ERP divergence. We recorded EEG data while participants did a binary-choice target recognition task in which the target was always either cat or dog (varied within-subject). Non-target stimuli included dogs, cats, and natural scenes with no animal. Dissimilar non-target waveforms diverged from target waveforms with a strikingly similar timecourse (roughly 150 ms post stimulus onset) and scalp distribution to that reported by Thorpe and colleagues. The difference between similar non-target and target waveforms differed. Both the time of divergence (350 ms) and the scalp distribution of target – non-target differences (central-parietal positivity) were reminiscent of a P300 effect. To explore the generality of this effect, we repeated the experiment with a different stimulus set, in which the target was always a male or a female face, and stimuli included male and female faces as well as images of non-face objects. Dissimilar non-targets and targets diverged with a similar timecourse and scalp distribution as seen in the cat/dog experiment. However, the difference between similar non-targets and targets had a more localized scalp distribution. These data are consistent with the theory that visual object recognition consists of a fast, feed-forward process that is adequate to make broad stimulus discriminations, and a slower process necessary to resolve detailed, specific representations, which may rely on feedback between visual areas.

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Perception and action: Cognitive factors

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

43.401 **Armed and attentive: Holding a weapon can alter attentional priorities in scene viewing**

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The weapons focus effect refers to a robust decrease in one's memory for scene details when a firearm is present. We conducted two experiments to determine whether this effect arises from changes in overt attentional control, and whether the effect can be modulated by the action capabilities of an observer. In Experiment 1, observers freely viewed as series of images for 5 seconds each while their eye movements were recorded. Each image portrayed an actor who was holding either a weapon or a harmless object. Dwell time on the object held by each actor increased for weapons over neutral objects, and longer looks toward the weapon were accompanied by a decrease in the time spent viewing the actors' faces. These results support the idea that the weapons focus effect has roots in the reallocation of overt attention during a viewing episode. In Experiment 2, the same procedures were repeated while observers were holding a non-functional pistol. These observers also looked at weapons longer than neutral objects, but, compared to the unarmed observers in Experiment 1, they spent less time looking at objects and more time looking at faces overall. By arming observers, then, the presence of a weapon in a display held less sway over their allocation of attention. This result extends the action-specific account of perception, which posits that the abilities of the observer affect his or her perception of the environment, to the allocation of attention. In this case, holding a weapon biased observers to focus on facial cues relevant for making threat-related decisions rather than the weapon itself. Hence, the action capabilities of an observer can override pervasive attentional biases such as weapons focus during scene viewing.

43.402 **"You were always on my mind": Action co-representation in Joint Simon tasks.**

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During joint actions, individuals coordinate their movements in space and time to achieve common goals. It has been suggested that action co-representation, a process in which co-actors represent each other's responses, facilitates joint action. One of the methods used to explore action co-representation, the Joint Simon (JS) task, has revealed that when pairs of individuals sit next to each other, participants' response times to targets presented in front of them are shorter than response times to targets presented in front of their partner. The action co-representation account of this effect holds that it emerges due to facilitatory and inhibitory processes that occur as a consequence of the representation of a co-actor's response. Guagnano et al. (2010), however, have argued against the action co-representation account, having observed that participants sitting in each other's extrapersonal space did not exhibit a JS effect in a JS task modified to reduce its social nature. Based on this null result, Guagnano et al. suggested that typical JS effects emerge due to a heightened social context and the spatial proximity of participants. To test and expand this alternative account, we conducted a series of experiments designed to map the spatial coordinates of the JS effect. The only consistent findings in these experiments, however, were JS effects when co-actors performed the task in extrapersonal space. Due to the contrast between our results and those observed by Guagnano et al., we attempted to replicate the key null effect using Guagnano et al.'s adapted version of the JS task. We found a significant JS effect in the extrapersonal space condition. Considering these studies together, we suggest that Guagnano et al.'s null effect was an anomaly and reassert that action co-representation is the process underlying JS effects.

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43.403 **A simple, intuitive method for computing confidence intervals in within-subject designs: Generalizing Loftus & Masson (1994) and avoiding biases of alternative accounts**

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Repeated-measures designs are common in the literature on motor behavior and, more general, in experimental psychology. Because of the correlational structure in these designs, calculation and interpretation of confidence intervals is nontrivial. One solution was provided by Loftus and Masson (1994). This solution, although widely adopted, has the limitation of implying the same-size confidence intervals for all factor levels and therefore does not allow assessment of variance homogeneity assumptions (i.e., the circularity assumption, which is crucial for the repeated measures ANOVA). This limitation and the method´s perceived complexity has sometimes led practitioners to use a simplified variant, based on a per-subject normalization of the data (Morrison & Weaver, 1995; Bakeman & McArthur, 1996; Cousineau, 2005; Morey, 2008). We show that this normalization method leads to biased results, and we provide a simple, intuitive generalization of the Loftus and Masson method that allows assessment of the circularity assumption. Using typical data from our own grasping experiments, we show to which extent these effects can affect the interpretation of experimental data.

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43.404 **Delays in using chromatic and luminance information for a simple reaction time task**

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The human visual system has three geniculate pathways that transmit information from the retina to cortex. The chromatic (L-M) and S-(L+M) pathways are thought to have slower conduction velocities than the achromatic (L+M+S) pathway and these delays may, in turn, result in slower reaction times (RTs) to chromatic stimuli. However, adjusting for individual differences in chromatic sensitivity and equating stimulus contrast across the three pathways are essential if we are to compare chromatic and achromatic RTs. Here, we measured chromatic and achromatic RTs over a range of contrasts and expressed them as functions of both detection thresholds and estimated neural activity. Chromatic stimuli were adjusted to be equiluminant to a grey background for each participant. Detection thresholds and JNDs were measured for chromatic and achromatic Gaussian blobs presented at 2° eccentricity. To generate accurate S-cone isolating stimuli we also measured participants' tritan lines using a sensitive 'transient tritanopia' procedure. We then measured the time it took subjects to raise a finger in response to the appearance of a calibrated Gaussian blob of a given chromaticity and contrast. RTs decreased monotonically as a function of contrast and RTs for achromatic stimuli were approximately 45ms faster than for chromatic stimuli. We model these data within the framework of a model that incorporates a first stage integrative yielding a strong stimulus contrast dependency and a second stage that converts decisions into motor activity.

43.405 **Visual and embodied perception of others: The neural correlates of the "Body Gestalt" effect**

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When we perceive others in everyday life, their bodies are often partially occluded. However, parts are perceived as belonging to the same person. High-level visual areas are known to automatically complete partially occluded objects, as revealed by classic "gestalt" phenomena. In contrast, body completion could rely on "embodied" processing in addition to visual processing. In other words, we suggest that humans use their own body repertoire to support visual perception in body completion. We developed a novel paradigm with largely occluded bodies to test if and how participants integrate faces and hands into a "body-gestalt" (BG) while imitating or observing finger movements. In 3 behavioural and 2 MEG experiments (+4 additional pilots), we consistently found that speed and accuracy of imitating a finger movement depended on the efficiency with which the stimulus configuration could be integrated into a BG. Moreover, our results revealed that BG completion was an "embodied" process and not purely visual, by showing that changing participants' postures modulated response times (and accuracy) 'online'. That is, body gestalt completion was shown to be most effective when the posture implied by the stimulus matched the participant's posture. Finally, in the MEG studies, the time-frequency analysis revealed a significant power difference in the α and β ranges between BG and noBG. The source localization of 14Hz oscillations (+/- 6Hz) revealed different generators depending on the implied postures of the stimulus configurations. For visually frequent postures (1st study), a power decrease was localized in the occipital cortex, confirming a predominantly visual process of BG completion. However, when the implied visual postures were less familiar (2nd study), we observed a significantly different power increase in prefrontal and parietal motor/bodyschema/attention areas during observation, supporting the notion that posture and/or motor resonance were crucially involved in the completion of less visually familiar body gestalts.

43.406 **Reliability of actors' and observers' gaze during natural tasks**

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Although eye movements are voluntarily controlled, gaze behavior while viewing complex, dynamic stimuli is highly consistent between individuals—people tend to look in the same place at the same time when watching commercially produced movies (Shepard et al., 2010; Hasson et al., 2008). Here, we assess gaze reliability while viewing natural motor tasks to address two questions. First, can action reliably direct the eye movements of a passive observer? Second, how are the gaze patterns of actors and observers related in space and time? We compared the gaze trajectories of "actors" engaged in a natural action task to those of "observers" who watched videos recorded from the actors' perspective. The actors made a peanut butter and jelly sandwich while their eye movements were tracked with a 30 Hz head-mounted eye tracker. Videos from the eye tracker's scene camera (capturing the actors' head-centered field of view) were presented to the observers. Observers' gaze was recorded with a 120 Hz remote eye tracker and downsampled to 30 Hz to allow comparison between actors and observers. Consistent with previous studies (Land et al., 1999; Hayhoe et al, 2003), actors' gaze was tightly linked to the task at hand: They fixated objects prior to reaching to them (e.g., knife prior to picking it up) and monitored ongoing movements (e.g., jelly jar while unscrewing lid). Videos from the actor's perspective evoked reliable gaze in the observers: Average intersubject correlations between observers was r = .38, on par with eye movement reliability while watching commercially produced movies (Shepard et al., 2010; Hasson et al., 2008). Moreover, the average intersubject correlation between actors and observers was r = .41, suggesting that observers' gaze was spatiotemporally linked with the actors' gaze.

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43.407 **Motor capability enhances visual sensitivity in the extrapersonal space**

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To perform a movement in a sophisticated and flexible manner, inputs from different sensory modalities needs to be gathered inside and outside the body. Such multisensory integration has been shown to occur in the peripersonal space, which immediately surrounds the body. Recent studies have reported improved visual processing in the peripersonal space. It was also shown that the peripersonal space can be extended when an agent uses a tool to explore the environment. Less is known, however, whether motor capability or tool-use affects visual representations of space distant from the body. Thus, the present study investigated the effect of extended motor capability on visual analysis in the extrapersonal space. Using a keyboard, participants manipulated a ball on the screen at a distance they could not reach by the hand. Their contrast threshold was measured before and after the manipulation task. As results, a group of participants who were able to control the ball showed improved visual sensitivity relative to those who passively watched the ball moving (Experiment 1). Furthermore, when participants could move the ball in a certain area of the screen but not in the other, improved visual sensitivity was observed only in the area where motor capability was experienced (Experiment 2A). The beneficial

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effect of motor capability, however, was not significant in the peripersonal space (Experiment 2B). Overall, the present study demonstrates that visual analysis of distant space can be improved by motor capability temporarily induced by tool-use. It further suggests that the sense of agency affects the representation of the extrapersonal space even without a physical connection between the body and the space.

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43.408 Hand position alters vision by biasing processing through different visual pathways

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The present study investigated the mechanisms responsible for the differences between visual processing for stimuli near and far from the hands. The idea that objects near the hands are immediate candidates for action led us to hypothesize that vision near the hands would be biased toward the action-oriented magnocellular (M) visual pathway that supports processing with high temporal resolution but low spatial resolution. Conversely, objects away from the hands are not immediate candidates for action and, therefore, would benefit from the perception-oriented parvocellular (P) visual pathway that supports processing with high spatial resolution but low temporal resolution. We tested this hypothesis using two important psychophysical correlates of the M and P pathways. Namely, we presented subjects with a spatial-gap detection task that involved high spatial frequency signals detectable by the P-cells, and a separate temporal-gap detection task which involved high temporal frequency signals detectable by the M-cells. Consistent with our prediction, we found better performance on the temporal-gap detection task and worse performance on the spatial-gap detection task for stimuli near the hands compared to the far stimuli. These findings suggest that altered visual processing near the hands may be caused by differential activation of the two visual pathways.

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43.409 Visual Control of Posture is Not Affected by Challenging Cognitive Tasks

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It is well known that postural stability is enhanced by stable structure in the periphery, whereas optical flow in the periphery can destabilize posture and create vivid perception of self-motion (vection). The question of interest here is whether cognitive processes can influence apparently automatic visual control of posture. Recent studies have found that cognitive tasks can influence postural control, suggesting that mental imagery and visual control of posture involve shared resources. We investigated the effects of two cognitive tasks — the Brooks Letter Task (visuo-spatial) and Speech Shadowing (auditory-semantic) — on the postural stability of participants while they observed the interior of a room, which filled the visual field. The virtual room was stationary in the "Static" condition; the room oscillated slowly (0.1 Hz) toward and away from the observer in the "Moving" condition. Throughout both conditions, participants stood on a transverse bar, which was mounted on a force plate. Dependent measures included stance breaks and fore-aft fluctuations of posture recorded by a force plate. The results showed that stance breaks and fore-aft variations of posture were significantly greater in the Moving as compared with the Static condition. FFT's confirmed that the differences in postural stability between Static and Moving conditions matched the frequency (0.1 Hz) of the oscillating room. Postural stability during performance of the cognitive tasks was no different than that during a control condition (no cognitive task). Our findings confirm the strong effects of peripheral visual stimulation on posture, and they indicate that this basic function is impervious to concurrent performance of both visual-spatial and auditory-semantic cognitive tasks.

43.410 Changes in visual performance and appearance before manual reach movements

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Goal. Saccadic eye movements and manual reaches affect visual processing. During movement preparation, visual performance increases selectively at the movement target. Previously, we have shown that the preparation of saccades also increases the perceived contrast of stimuli at the target location, suggesting a strengthening of the neural representation (Rolfs & Carrasco, 2010). Here we examine the time course of visual performance and perceived contrast around the time of goal-directed reach movements. Method. On each trial, observers placed their index finger at the middle of a touch screen, just below the point of fixation, and two standard stimuli (vertical Gabors, 22.4% contrast) flashed 7º on either side of fixation. Shortly after, a central cue indicated the target of a reach movement and observers quickly executed the reach while keeping fixation. At a variable time after the cue, either before or after the reach, a second set of stimuli appeared at the two locations. These test stimuli differed from the standard both in contrast (seven levels centered on the standard's) and in orientation (±75% orientation threshold). After the reach, a post-cue indicated one of the two stimulus locations and observers reported both the orientation (clockwise or counterclockwise) and the contrast (higher or lower than the standard) of the test stimulus in a single button press, providing measures of both visual performance and perceived contrast. Results. Observers had better discrimination performance at the reach target than at the opposite location, consistent with earlier findings. More importantly, as time approached reach onset, the test contrast necessary to subjectively match the standard's contrast decreased at the reach target relative to the opposite location. These results show that reaches improve performance and alter appearance. Thus reaches, akin to saccadic eye movements, seem to influence the visual representation of their targets.

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43.411 Prediction of action's visual Consequences: Preactivation Model & Psychophysics

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It has been shown that the visual system is subject to sensory attenuation (Cardoso-Leite, Mamassian, Schutz-Bosbach, & Waszak, 2010). This phenomenon is thought to be related to motor based sensory prediction. In this study we first develop a model to account for how this prediction might be implemented in the brain. This model supposes that the voluntary action selection involves the preactivation of learnt action-effects (Waszak, Cardodo-Leite, Hughes, 2011). By modeling motor induced preactivation in sensory pathways we predict that sensory attenuation is due to a nonlinear increase of the internal response. One novel prediction of this model is that it should result in a change of contrast discrimination sensitivity for correctly predicted action effects. We tested this hypothesis by conducting a contrast discrimination task for visual stimuli that were either congruent or incongruent with previously learnt action-effect contingencies. Participants freely selected on each trial which of two buttons to press (one with each index finger). Each button press was followed, with a delay of 200ms, by the presentation of either an A or an H, at one of two contrast levels (C0 and C1, individually determined to produce a contrast discrimination sensitivity d' of 2). On each trial, participants were required to report the perceived contrast of the visual stimulus. We observed a significantly ($F(1,11) = 5.59$, $p < 0.05$) reduced contrast sensitivity for trials where the stimulus was congruent (M=1.82 SEM=0.56) with the learnt action-effect contingency, compared to when it was incongruent (M=1.98 SEM=0.61). Hence the prediction made by our preactivation model was confirmed and provides a new way to consider how the brain predicts the sensory consequencies of the action.

43.412 When is error-correction just error-correction?

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Many real-world tasks such as interception and navigation require model-based prediction to anticipate future conditions for successful planning and execution of motor responses. In these contexts, error is minimized through accurate model acquisition. Learning the correct model requires accruing a rich set of task information. Response errors enhance this knowledge as different strategies are tested with variable success. We hypothesize that error-correcting actions may not only serve to immediately improve performance, as often concluded from sequential trial dependencies in visuomotor behavior, but also enhance visuomotor training via exploration of model space. We tested this hypothesis using a visuomotor task we call the

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"helicopter task", in which observers pilot a helicopter through a tunnel by controlling its acceleration, avoiding collision with obstacles and the tunnel itself. Successful planning and execution requires model-based prediction of the helicopter's dynamics and effects of currently applied controls down the tunnel. The dynamics model comprises the rate of acceleration (control exerted), and the rate of falling (no control exerted). As expected, experience improved observers' piloting ability: they navigated farther through the tunnel without collision. To assess the degree to which they learned and used the dynamics model, two test tasks were interleaved among piloting sessions. In these tasks, observers adjusted the helicopter's horizontal position at a fixed, but variable vertical distance from a target in order to ensure contact when released with the controls on (upward acceleration) or turned off (downward drift). Performance in these tasks revealed strong initial sequential trial dependency, yielding responses highly-correlated with previous trial errors that reduced overall response bias. With increased training, this sequential dependency gave way to model-based performance revealed by error dependencies on the vertical distance from which the adjusted helicopter was launched. These results support our hypothesis and demonstrate an important role for error-correction in visuomotor model learning.

43.413 Hand dominance influences outcome predictions when observing self-generated actions

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When people observe an action, how do they predict its outcome? Knoblich and Flach (2001) proposed that people simulate performing observed actions to predict their effects. They found that people were more accurate in predicting the outcome of an action when viewing videos of themselves than when viewing videos of another person. Presumably, when people watched videos of themselves, the system that performed the original action also simulated the action during perception and this match yielded more accurate predictions. We sought to investigate and extend this simulation hypothesis. We filmed participants (N=13) throwing Velcro balls at two targets from an allocentric (profile) viewpoint and an egocentric (over-the-shoulder) viewpoint. Participants made throws with their dominant and non-dominant hands. We subsequently asked participants to predict the trajectory of their own throws and another participant's throws as they watched videos spanning the onset of the throwing motion to the last frame before release. Participants made more accurate predictions when they viewed videos taken from an allocentric viewpoint compared to an egocentric viewpoint regardless of whether they watched their own throws or another's throws. Interestingly, participants' predictions were also more accurate when they viewed a throw performed with the dominant hand than with the non-dominant hand, but only when they observed their own actions. This result provides new support for the simulation hypothesis: participants were more accurate in predicting throws they made with their own dominant hand because they used the same system to both generate and simulate these actions. The fact that participants were no more accurate in predicting the outcome of throws made with their non-dominant hand than they were in predicting throws made by another actor also suggests that people automatically make predictions that guide perception based on dominant hand simulations, regardless of which hand they observe.

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43.414 Perceptual learning of bimanual coordinated rhythmic movements: Information matters more than movements

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Prior to training, only two coordinated rhythmic movements are stable: 0° and 180°. Other coordinations (e.g. 90°) must be learned. This pattern emerges from a task dynamic in which relative phase is perceived as the relative direction of motion, modified by the relative speed (Bingham, 2004). People can learn how to move at 90° but this entails learning to use a different information variable (relative position; Wilson & Bingham, 2008). Learning a novel coordination requires feedback, however, and typically this feedback is presented in the form of a transformed display such as a Lissajous plot. This display removes relative motion of any kind as a source of information about relative phase and simply requires people to track a template; as a result, people can move at any required coordination with brief practice. Wilson et al (2010) developed a second form of feedback, coordination feedback, which doesn't alter the information available for relative phase and preserves relative position as an option. The current study directly compared the two feedback methods. 12 participants learned to move bimanually at 90° using either Lissajous (N=6) or coordination (N=6) feedback. We tested coordination stability with both displays in baseline, post training and retention sessions, with baseline and post training separated by 5 training sessions. Both feedback methods improved performance at 90°, but there was no transfer of this learning between the feedback displays. The two feedback methods create different task dynamics that are informationally distinct from one another, and participants learned to use different information to support their actions. This result confirms that a) the two feedback methods provide different perceptual information and that b) perceptual learning underpins the improvements in movement stability, even in the bimanual version of the task. Information is a key part of a perception-action analysis of this task (Bingham, 2004).

43.415 Statistics of natural action structures and human action recognition

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Humans can easily detect, recognize, and classify a range of actions very quickly. Despite enormous research efforts, what spatial-temporal features should be encoded and what statistics of these features are in natural human actions are still unknown. In this work, we proposed natural action structures, i.e., multi-size, multi-scale, spatial-temporal concatenations of features, as the basic encoding units of natural human actions. We took several steps to compile these structures. First, we sampled a large number of sequences of circular patches at multiple spatial and temporal scales. The spatial and temporal scales were so coupled that the sequences at finer spatial scales had shorter durations. Second, we performed independent component analysis on the patch sequences and classified the obtained independent components into clusters using the k-mean method. Finally, we compiled a large set of natural action structures with each corresponding to a unique combination of the clusters at all the spatial and temporal scales. We examined the statistics of these natural action structures and selected a set of highly informative structures for action recognition. To evaluate the utilities of these natural action structures, we used them as inputs to two widely used methods for pattern recognition, i.e., Latent Dirichlet Allocation and Support Vector Machine, to classify a range of human actions in the popular KTH and Weizmann datasets. We found that natural action structures obtained in this way achieved a significantly better recognition performance than simple spatial-temporal features and that the performance was better than or comparable to the best current models. We thus concluded that natural action structures can be used as the basic encoding units of human actions and activities and may hold the key to the understanding of human ability of action recognition.

43.416 Hand Representations in Parietal versus Temporal Cortex: Seeing You Touching Me?

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Visual representations of body parts have been identified in both ventral and dorsal pathways. In body part selective regions in occipitotemporal cortex (Extrastriate Body Area, EBA), representations are thought to reflect the visual appearance of body parts. In parietal cortex, however, representations are primarily thought to reflect observed actions. Here, we used fMRI to investigate visual responses to the sight of body parts being touched. First, we compared responses to the sight of a static hand being brushed compared to brush alone, revealing the expected activation in EBA but also robust bilateral activation in anterior parietal cortex. We then characterized responses in both regions in three separate experiments. Experiment 1 revealed that in both regions, the sight of brushing near, but not on the hand was sufficient to elicit strong responses. Further, there was no modulation by hand laterality (left or right). However, in parietal cortex, but not EBA, viewing a static hand alone elicited weak activation, suggesting that the combined presence of an object and a hand is necessary. Experiment 2 showed little effect of perspective in either region comparing egocentric and allocentric views. Experiment 3 revealed specificity to both body part and type of action in parietal cortex but not EBA. In particular, activity in

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parietal cortex was reduced for seeing a foot being brushed compared to hand being brushed, and for finger movement compared to a hand being brushed. Finally, we compared selectivity for touching with selectivity for hand actions in parietal cortex (Shmuelof and Zohary, 2006) revealing adjacent but non-overlapping regions. Our results demonstrate the presence of body part representations in parietal cortex reflecting the interaction between static hands and objects, with those in EBA mainly reflecting the presence of a body part.

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43.417 The effects of TMS over PPC in a visual feature memory / saccade task

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Introduction: Perception and action are often treated separately, but ultimately perception must be used to guide meaningful actions when object selection and memory are required. We investigated the role of parietal cortex areas known to be involved in saccade and reach planning (the mid-posterior intraparietal sulcus [mIPS] and the superior parietal-occipital cortex [SPOC], see Vesia et at. J. Neurosci., 2010) in a delayed match-to-sample saccade task, based on single or multiple visual features. Methods: 4 Head-fixed subjects were shown a 'probe' template with a conjunction of two features (shape and texture) at central fixation for 500 ms, and instructed to remember the shape, texture, or both features before each trial. After a delay, subjects were presented with a mask followed by stimuli in four eccentric quadrants for 1 second. Afterwords, subjects were required to saccade to the location of the stimulus that matched the remembered probe. Task difficulty was set during preliminary psyhophysical experiments. Eye movements were tracked using an Eyelink II. During the delay period after the presentation of the probe, 3 TMS pulses (10Hz) were delivered to right mIPS (thought to be involved in both saccades and reach), right SPOC (thought to be involved in just reach), or Cz (control site), run in blocks randomly intermingled with no-TMS trials. Results: For each TMS site, we analyzed subject performance (ability to saccade to the correct object) with a 3(feature condition)x2(visual field)x2(TMS/no TMS)x6(subjects) mixed-model ANOVA, with subjects as a random factor. There was a significant main effect of TMS in the right mIPS condition, but not in the right SPOC or Cz conditions. Conclusion: TMS to the right mIPS (but not right SPOC) disrupted non-spatial feature memory in a match-to-sample saccade task. This may implicate mIPS in an effector-specific network that coordinates feature memory with the planning of action.

43.418 Preservation of size constancy for action, but not perception, in a patient with bilateral occipital lesions

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Size constancy is not only necessary for maintaining perceptual stability of the visual world but it is also critical for goal-directed actions such as grasping an object. To grasp an object successfully, one must pre-shape the hand to match the real size of the object even though the retinal image size will vary as a function of viewing distance. The neural mechanisms that underlie size constancy for perception and action are poorly understood. We therefore carried out two experiments with patient M.C., who has large bilateral occipital lesions. In the first experiment, we measured M.C.'s ability to estimate the perceived size and distance of a series of filled black circles that differed in physical size. The stimuli were positioned at varying distances such that their retinal image size was either matched or differed systematically. M.C.'s size and distance estimates were poorly scaled to the physical size of the stimuli and were correlated instead with the retinal image size of the stimuli. Would M.C.'s grasps be similarly governed by retinal image size? We asked M.C. to manually estimate or to reach out and pick up Efron blocks positioned at different distances. As expected, M.C.'s manual estimates were poorly scaled to object width yet well correlated with their retinal image size. But when M.C. reached out to pick up the objects, her grip aperture scaled to object width at all distances while her hand velocity scaled to object distance. Importantly, her grip aperture was not governed by the retinal image size as one would expect if M.C.'s visuomotor system relies on conscious percepts. Taken together, our results strongly suggest that the neural mechanisms that underlie size constancy for perception and action are distinct, and lend further support for models of visual function that separate conscious visual perception from action.

Acknowledgement: OMRI, CIHR

43.419 On the Relationship Between Execution, Perception, and Imagination of Action.

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Humans are able to perceive, imagine, and execute movement. Studies investigating these abilities typically employ variants of the Fitts aiming task because Fitts' equation captures the way in which movement time (MT) is adapted to maintain accuracy as movement amplitude and target width change. In separate studies, it has been demonstrated that the Fitts relationship is present in movement execution (Fitts, 1954), perception (Grosjean et al., 2007), and imagination (Decety & Jeannerod, 1996). The consistent emergence of Fitt's relationship in all three tasks has lead the researchers to suggest that the core process underlying imagination and perception is a motor simulation process where the response codes used in execution are activated offline. The present study was designed to test this hypothesis by being the first study to assess the characteristics of the Fitts relationship for movement execution, perception, and imagination within the same group of individuals. Participants were asked to imagine and perceive reciprocal aiming movements at varying Indices of Difficulty (Fitts, 1954) before and after performing the movements. If response code-based motor simulation is the core process of action imagination and perception, then: 1) the characteristics of the regression lines should be similar across different tasks; and 2) the performance of the movement task should increase the accuracy of action perception and imagination. Consistent with these predictions, the analyses revealed that the Fitts' relationship held across all conditions and that there were no differences in slopes across conditions. Importantly, the y-intercept of the lines for imagined MTs was significantly closer to the y-intercept for the execution MTs in the Post-Execution condition. A non-significant trend toward a Post-Execution improvement in action perception was also noted. Overall, the results support the notion that action perception, and imagination have an underlying common response code-based motor simulation process.

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43.420 Functional Dissociation between Perception and Action is Evident Early in Life

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The functional distinction between vision for perception and vision for action is well documented in the mature visual system. Ganel and colleagues recently provided direct evidence for this dissociation showing that while visual processing for perception follows Weber's fundamental law of psychophysics, action violates this law. We tracked the developmental trajectory of this functional dissociation, asking (a) whether the qualitatively different pattern observed in adults of adherence of perception but not of action to Weber's law would also be evident during early childhood, and (b) how early in life the adherence of perception to this fundamental law of psychophysics becomes adult-like. Children aged 5-8 and adults were asked to either estimate the size of discs (perception), or grasp discs (action) varying in diameter. Interestingly, variability of perceptual estimates increased as a function of object size in accord with Weber's law, while variability of grasping did not scale with object size, at all ages tested. The results also revealed, however, developmental changes in the adherence of perception to Weber's law: while adults demonstrated a linear increment in JNDs with object size, the changes in JNDs for both the 5- to 6- and 7- to 8-year-olds were best described by a quadratic fit. Adult-like pattern of linear increment in JNDs as a function of object size was observed only after the age of 10.These results provide the first clear evidence for an early emergence of the dissociation between perception and action. However, developmental

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changes in visual sensitivity to changes in object size suggest the refinement of the perceptual system in its sensitivity to relative metrics of the visual world during childhood.

Natural image statistics

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

43.421 Interpolation of Luminance at Missing Points in Natural Images

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The statistical regularities of natural images allow a visual system to interpolate missing or occluded image points with some accuracy. In previous work1, we obtained a tight (near-ideal) lower bound on how accurately missing pixel values in gray-scale natural images can be estimated. Here we measure how well the human visual system estimates gray-level at missing image locations and then compare performance against the near-ideal observer and several other models that incorporate natural image statistics and/or known low-level properties of the human visual system. On each trial of the experiment, one of 62 gray-scale natural image patches was presented to the observer. Psychometric functions were measured by varying the gray-level of the central pixel and asking the observer to respond whether the central pixel appeared too bright or too dark (pixel size = 4 arcmin). No feedback was given. The interpolated gray-level estimated by the observer was taken to be the midpoint of the psychometric function. For each natural image, two patch sizes were tested: a large size (128x128 pixels) that provided full spatial context, and a small size (5x5 pixels) that provided only the neighboring 24 pixels. Our results reveal that human performance is very similar for the 128x128 and 5x5 conditions, suggesting that human gray-level interpolation results predominantly from local image computations. Humans underperform the near-ideal observer, but outperform simple models that compute the average, median, or mode of surrounding pixels, suggesting that humans exploit some but not all of the local statistical structure of natural images. The best current model for human gray-scale interpolation performance is one that exploits the statistical structure of local contrast rather than local gray-scale and incorporates the psychophysical effects of contrast masking. 1Geisler & Perry (2011), Journal of Vision, (11)12:14 1-17.

43.422 The gist of the organized is more precise than the gist of the random

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We can extract summary information (e.g. average size, orientation or color) about entire sets of objects without having precise information about individual items. If we have a set of lines, how does the organization of that set influence the assessment of the mean orientation? Displays consisted of 36 lines in a 6x6 grid. The "structured" displays were randomly sampled from larger fields of lines organized with 2D sinusoidal variations in orientation. Structured subsets were chosen so that the center lines were not reliable predictors of mean orientation. For each structured 6x6 display, a "jumbled" display was created by randomizing the positions of the lines. In Experiment 1, displays were shown for 300ms. Participants estimated average orientation by subsequently adjusting a test line to the perceived average. The average absolute error was significantly lower for structured displays (20 vs 25 degrees, p<0.001). Average error increased for both trial types as the variance of orientations in the display increased. The average signed error (as opposed to absolute) was not significantly different from zero in either trial type, indicating that participants did not have a systematic bias in their responses. In Experiment 2, we varied the display duration (100-500 msec). The benefit of the structured display persisted at all display durations. Furthermore, there was no significant effect of presentation time on average errors for either trial type, suggesting that this is a global process that does not benefit from serial scrutiny of individual items. As shown previously, mean orientation is extracted from displays very rapidly. The present results show that the structure of the field is extracted as rapidly and can be used to improve assessment of the mean.

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43.423 Regularities in the Anisotropic Content of Portrait and Landscape Paintings: A Corollary to the Horizontal Effect Anisotropy of Visual Processing

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Structural content in natural scenes is biased in spatial scale (1/frequency) as well as orientation (H>V>>Oblique), and neural encoding appears to "undo" (whiten) these biases (Simoncelli & Olhausen, Annu. Rev. Neurosci. 2001; Essock et al., JOV 2009; Hansen & Essock, JOV 2004). Thus, when an artist paints a landscape, we might expect that it contains the same biases to look "right"--if it didn't, the most prevalent scales and orientations would be over-emphasized by the anisotropic suppression. Recently, the relationship between the structure of natural scenes and paintings has been explored (e.g., Graham & Field, Perception 2008; Graham, Friedenberg, & Rockmore, VisCog 2010). Specifically, we have reported that artists actually overemphasize the anisotropies found in natural scenes in their paintings (Schweinhart, Kim, & Essock, JOV 2010). Here, we compared the statistical properties found in portrait paintings to natural scenes and photographs of faces. There is some indication (Redies et al., Network 2007) that the amplitude spectra of portraits are closer to those of scenes than faces, but the orientation spectra of portraits has yet to be studied fully. Paintings were photographed every 3o (avoiding a discrete transform bias; Hansen & Essock, 2004). The images were then analyzed by fast Fourier transform (FFT) and power at different orientations was compared across spatial frequency. Scenes show a strong horizontal-effect anisotropy (H>V>>Ob) that doesn't vary with spatial frequency while faces show no anisotropy. Interestingly, paintings of both landscapes and faces show the anisotropy both with increasing magnitude and spatial frequency, even though the pattern is not present in all types of subject matter.

43.424 Three-Dimensional Natural Scene Statistics: Dependencies between Luminance and Range Contrasts

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Computing relative or absolute range (egocentric distance) is difficult because, of course, neither is specified in any direct way by the 2D retinal image. If, however, there was a relationship between range and luminance or color, perhaps it could be exploited to yield fast, initial estimates of range from the retinal image per se. We studied the statistical dependence between range (and disparity) contrast and luminance contrast across random point-pairs in natural scenes, and found that changes in range and luminance are highly dependent. We collected high resolution range maps of natural scenes co-registered with luminance (RGB) images using a Riegl terrestrial scanner, co-mounted camera, and in-house software. Various alternative preprocessing stages were used to simulate the early stages of visual processing (e.g. foveation). Our basic approach was to randomly sample pairs of points in the scenes to determine if the change in range or luminance or both exceeded some criterion. We then 1) compared the conditional density of range edges given luminance edges to the (unconditioned) density of range edges and 2) compared the joint distribution of range and luminance contrast to the product of their marginal distributions. We found a robust statistical dependence between range and luminance. Additionally, we computed difference surface maps (between the joint distributions and product-of-marginals predicted by independence). These difference surfaces reveal which regions of luminance and range change exhibit the strongest statistical dependencies. The statistical dependence between luminance and range allows the construction of models where one can assign a probability of occurrence of a range edge given a luminance edge at a particular point in a scene. In principle, such a mechanism could also be used by biological visual system to serve as priors when reconstructing the 3D environment from 2D image data.

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43.425 Amplitude Spectrum Slope is More Important than Orientation in Rapid Scene Categorization

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Recently, we have shown that phase-randomized natural scene images are more effective than white noise masks at disrupting rapid scene-categorization performance in a backward-masking paradigm (Loschky et al. 2007; Loschky, Hansen et al., 2010). This is interesting because phase-randomized scene masks possess identical second-order statistics to their non-phase randomized counter-parts, while white noise masks possess no second-order statistical relationships. Thus, the second-order information contained in phase-randomized masks is processed at a level that interferes with rapid scene categorization. However, phase-randomized scenes differ from white noise by possessing $1/f\alpha$ ($\alpha = 1.0$) amplitude spectra with biases at the vertical/horizontal (i.e., cardinal) orientations. Here, we examined which aspect of the amplitude spectrum is responsible for masking. Specifically, is it a) the slope of the amplitude spectrum in phase-randomized masks, or b) the biases at different orientations, or c) both, that produce interference in rapid scene categorization for $1/f\alpha$ ($\alpha = 1.0$) noise as opposed to white noise ($\alpha = 0.0$)? Target images were backward-masked by random-phase noise differing in slope and orientation bias at several SOAs. Target stimuli were from 6 scene categories (beach, forest, airport, street, home interior, and store interior). Mask stimuli were randomized phase noise having one of four different amplitude spectrum slopes (0.0, 0.5, 1.0, and 1.5). Within each slope set, we varied the cardinal orientation bias (5 levels from no-bias to maximal bias). The results showed that the amplitude spectrum slope drove the masking effects, with a slope of 1.0 masking scenes most, followed by 0.5, 1.5, and 0.0 respectively, but with little influence of mask orientation bias. Furthermore, the effects of slope were greatest early in scene processing (33ms to 67ms SOA). Lastly, control experiments verified that the masking effects cannot be accounted for by differences in perceived contrast of the noise masks.

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43.426 **Size matters: Increasing stimulus size reduces thresholds in an amplitude spectrum discrimination task.**

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The relation of spatial content to spatial scales falls at a $1/f\alpha$ in natural scenes (Field, 1987). Previous studies have demonstrated that the primate visual system is sensitive to this regularity by investigating peak alpha discrimination sensitivity. The findings surrounding human sensitivity have shown to vary considerably, ranging from peaks in sensitivity of alphas (i.e., amplitude spectrum slope) between 1.0-1.3, or peaks across the entire range of alphas – excluding 0.8 (Knill et al., 1990; Tadmore & Tolhurst, 1994; Hansen & Hess, 2006), while still, some have found no peak sensitivity across all alphas (Thompson & Foster, 1997; Johnson et al., 2011). One possible account of these differences may lie in the size of stimuli previously presented to participants, which has ranged widely from 0.75° to 10° of visual angle. Although the $1/f\alpha$ relation has long been considered scale invariant (Field, 1987), it is likely that alpha discrimination may be benefited at coarser scales, therefore reducing thresholds and affecting peak sensitivity. We presented 7 different stimulus sizes (ranging from 1° to 8° in steps of 1.84) at the fovea and measured alpha discrimination sensitivity of 1/f noise stimuli. Results indicate that sensitivity to select alphas disappeared when stimulus size increased and surpasses 2° of visual angle, while smaller sizes exhibited similar peak sensitivity (1.0 – 1.3) as was found in more recent studies (e.g. Hansen & Hess, 2006). In addition, overall alpha discrimination thresholds decreased as a function of stimulus size and demonstrated a size tuning to the amplitude spectrum slope, which explains part of the variability between measured thresholds of studies that presented small stimuli (Knill et al., 1991) as opposed to larger stimuli (Johnson et al., 2011; Thompson & Foster, 1997).

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43.427 **Natural image statistics based population coding for local edge probability**

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A key computation in the visual cortex is the extraction of object contours, where the first stage in the process is thought to be local edge detection by V1 simple cells. From an engineering perspective, however, individual Gabor-like receptive fields exhibit relatively poor localization and orientation tuning on natural object contours. Higher quality information about object boundaries can in principle be decoded from the pattern of activity over the local population of simple cells in the vicinity of an object edge. To understand how local excitatory and inhibitory interactions among simple cells can best be used to estimate local edge probability in natural scenes, we used Bayes rule to compute P(edge @ x,y,theta | r0,r1...rN) where r0 is the response of the linear filter at (x,y,theta), and r1...rN are the responses of other filters in the vicinity of (x,y,theta). We modeled the joint distribution P(r0,r1...rN | edge {or ~edge} @ x,y,theta) based on (1) measurements of individual filter statistics on and off edges in natural scenes using human ground truth labels, and (2) simplifying assumptions about the dependencies between filter responses in the vicinity of an edge. The resulting "formula" for computing local edge probability, expressed in a 2-layer format (sum of sigmoids of sums), led to significantly improved localization of edges both in space and orientation, improved precision-recall measures compared to the linear filter, and visually improved edge detection results. This also suggests a biologically-plausible scheme for combining neuronal responses through local feedforward excitatory and inhibitory interactions.

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43.428 **Phase Randomization of Natural Color Images with Simultaneous Preservation of First and Second Order Statistics**

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Natural images are widely used as stimuli in studies of both lower and higher level visual functions. A commonly used method to distinguish effects related to the second order statistics of natural images from those related to higher order ones is to produce phase-randomized versions of the original stimuli, but with a similar power spectrum, and use them as controls. This approach, however, has major shortcomings. Phase randomization may produce a wider distribution than the original one, possibly with values of intensity outside of the range of the display. Rescaling the values of a randomized image to fit into the desired range would inevitably change the power spectrum as well. In particular, for color images, phase randomization is typically applied to each of the color channels while keeping the original phase differences between channels. With this traditional approach, the 3D joint distribution of original colors is not preserved and could result in substantial differences in color appearance of the phase randomized images which limit their applicability as control stimuli in color vision research. We introduce a method for image randomization that is based on an iterative approximation scheme (a generalization of the IAFFT algorithm; Schreiber & Schmitz, 1996) and which closely preserves the power spectrum of the original image and its exact intensity or 3D color distribution. Applying our algorithm on a collection of natural images revealed that imposing distribution constraints on phase randomized color images results in images with notably closer appearance to that of the original image, not only in color but also in their coarse spatial structure. Our observations suggest that the perceptual information content of first and second order statistics of natural images, when considered jointly, is greater than has been previously appreciated and our proposed method provides means for a reevaluation of their utility in biological vision.

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43.429 **Surround suppression of contrast sensitivity with natural scene stimuli**

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Contrast sensitivity for Gabor targets is largely suppressed when embedded in a sinusoidal grating surround and presented at eccentricities ≥1° of visual angle, with suppression being narrowly tuned to orientation and spatial frequency (Petrov, Carandini, & McKee, 2005). However, the real-world environment is not narrow-band. The current study therefore investigated whether or not surround suppression of contrast sensitivity for natural scene targets exhibits a narrow tuning to the known statistical

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regularities of scenes, specifically the power spectrum slope (i.e., contrast distribution across spatial frequency), structural sparseness (i.e., edge density), and orientation bias. Accordingly, all stimuli (targets and surrounds) were selected such that the power spectrum slope was constant at -1.2, -1.8, or -2.6 (i.e., -0.6, -0.9, or -1.3 in terms of the amplitude spectrum). Within each slope constant, the amount of structural sparseness was systematically varied (2-3 levels). Lastly, the oriented content of all the stimuli was fixed (isotropic or anisotropic) across all levels of power spectrum slope and structural sparseness. Target stimuli consisted of variable rms-contrast circular natural scene patches (1.17° diameter) embedded in fixed high rms-contrast natural surround annuli (4.11° outer diameter), and all stimuli were presented at 3° eccentricity. Threshold contrast sensitivity for detecting natural image targets was assessed with a standard spatial 2AFC staircase protocol, either alone or embedded in natural scene surrounds. For isotropic targets and surrounds, the results show that target contrast threshold suppression was significantly modulated by the power spectrum slope and structural sparseness of the targets, but not the surrounds. A similar trend was observed for anisotropic targets and surrounds, except that the structural sparseness of the surrounds significantly modulated suppression. Such findings preclude an account based on simple inter- (or intra-) channel interactions as a function of available global contrast as it relates to the contrast sensitivity function.

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43.430 **Statistics of edge profiles in natural scenes**

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It is widely known that edges in natural scenes are formed by both luminance and texture differences between two objects. However, little effort has focused on studying the statistical properties of such edges. Computing these statistics could provide important insights into how the visual system processes natural scenes. Ten high-resolution natural scenes were selected from the McGill Color Image Database. Three human subjects traced the edges of occlusion boundaries on grayscale versions of the images. Patches of size 80x40 pixels, centered on the marked edges, were extracted for analysis. The 5000 extracted edge patches were then aligned in terms of polarity (brighter side on top). We analyzed the edges in both linear and log luminance domains. First-order statistics revealed that the mean edge is a blurred step in luminance with greater variance and less skewness in the brighter half than in the darker half. The distribution of Michelson contrast between the brighter and darker halves is uniform with a bias towards low contrast. We also classified the edge patches into four categories: (1) Luminance-defined edges, which have high contrast and small standard deviation. (2) Textured-defined edges, which have low contrast and high standard deviation. (3) Luminance-textured edges, which have high contrast and large standard deviation. (4) Object-defined edges, which exhibit neither a difference in luminance nor a difference in texture between the two halves; these edges likely contain boundaries that subjects marked via interpolation/extrapolation based on object recognition. Approximately 40% of the edges were luminance-defined, 10% of the edges were texture-defined, 32% of the edges were luminance-textured edges, and 18% of the edges were object-defined. We discuss the implications of these findings for neural and computational coding. In particular, edge detectors and various wavelets have been tuned to detect luminance-defined edges; such templates would fail on 30% of occlusion boundaries.

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Visual memory: Encoding and retrieval

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

43.431 **Presenting and testing sets of memory items simultaneously or sequentially do not affect change detection performance**

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Classic studies of short-term memory have used a sequential presentation method for memory items whereas many of recent visual short-term memory (VSTM) studies have used a change detection paradigm in which items for memory are presented at the same time. Despite the fact that the sequential presentation of memory items can lead to a different temporal context for VSTM encoding compared to the simultaneous presentation, only few studies have addressed a concern about whether such contextual difference in the testing paradigms may lead to a substantial difference in VSTM performance. In the present study, we tested if presenting two sets of memory items sequentially can lead to any significant difference in change detection performance compared to presenting the sets simultaneously. In Experiment 1, subjects were asked to remember colors of six memory items that would be either displayed simultaneously or displayed sequentially with two subsets of three items. For a test array for change detection, we also presented test items either simultaneously or sequentially. In Experiment 2, we manipulate display set size into 2, 4, 6, 8 items across the simultaneous and sequential presentation conditions. We found the patterns of change detection accuracy between the simultaneous and sequential presentation conditions were virtual identical to each other, and found no difference even when the setsize was manipulated. The results indicate that the presenting memory items simultaneously or sequentially does not affect the change detection performance, and suggest that temporal context for VSTM encoding may not play a significant role for accurate formation and recognition of memory representation in change detection.

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43.432 **Active retrieval from long-term memory aids change detection**

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The current study further examined the hypothesis that post-cues can encourage the retrieval of long-term memory (LTM) representations and lead to improved change detection performance (Beck & van Lamsweerde, 2011) using a gaze contingent change detection task. Nine objects were presented and after seven objects were fixated, a brief blank screen was presented followed by the test image in which one item changed identity or all items were unchanged. The potential change object was either cued in the test array or not cued. The change object could be any of the seven items fixated prior to the change (lags 0-6) or one of the two items never fixated. The availability of identity information in the periphery was manipulated by using a moving window technique for half of the participants. When an object was not being fixated, it was blurred so that its location was visible but its features were not. Change detection performance was better for the cue trials than the no-cue trials at all lags for both the moving-window and no-moving-window conditions. When there was no moving window, the cue benefit was also found for objects that were never fixated. However, when the moving window was used, performance on the cue trials was not better than performance on the no-cue trials for items that were never fixated. Therefore, cues do aid change detection performance for items no longer stored in visual working memory (~lags 3-6), and cues improve change detection performance for items that were never fixated if features can be identified in the periphery. Furthermore, fixating the change object in the test array was predictive of accurate performance for the cue trials, but not for the no-cue trials, suggesting that the cue does encourage LTM retrieval that does not necessarily occur without a cue.

43.433 **Saccade execution, not covert attention, leads to automatic encoding of distractors into VWM**

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Visual attention plays an important role in encoding objects into VWM (Schmidt et al., 2002). According to one view, VWM and visual attention may reflect the same mechanism (Theeuwes et al., 2009), in which case covertly attending an object should be equivalent to encoding that object into VWM. Alternatively, saccade execution, rather than covert attention, may be the central factor controlling VWM encoding. VWM spans gaps in perceptual input, and a perceptual gap is generated only when a saccade is executed. Thus, VWM consolidation may be tied most directly to pre-saccadic shifts of attention. In the present study, we tested the roles of

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overt and covert orienting in the automatic encoding of items into VWM. Attention was manipulated during the retention interval of a color change-detection task. Participants either overtly (Experiments 1 and 2) or covertly (Experiments 3 and 4) attended to a task-irrelevant distractor. Distractor encoding was measured by its interference with color memory. The results of Experiments 1 and 2 showed a significant decrease in color memory performance when participants executed a saccade to the distractor object but not when they executed a saccade to empty space. In Experiments 3 and 4, participants covertly shifted attention to the distractor in order to detect a rare onset or discriminate a target presented at the distractor location. Covert shifts of attention did not generate a significant decrease in color memory performance. Participants could strategically avoid encoding a covertly attended object into VWM. Together, the results indicate that encoding of an attended object is automatic only when the shift of attention to that object precedes a saccade. These results challenge the view that visual attention and VWM reflect the same mechanism while supporting the view that perceptual gaps created by saccades necessitate automatic encoding of the saccade-target item into VWM.

43.434 Obligatory encoding of task-irrelevant features depletes working memory resources

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Selective attention is often considered the "gateway" to visual working memory (VWM). However, the extent to which we can voluntarily control which features enter memory is debated. Current models describe VWM as a limited resource shared out (continuously or discretely) between elements of a visual scene. Consequently, as memory load increases, the fidelity with which each visual feature is stored decreases. Here we used changes in recall precision to probe whether task-irrelevant features were encoded into VWM when individuals selectively attended to specific feature dimensions. We examined the resolution with which individuals could reproduce from memory the orientations or colors of items presented in sequential displays. Recall precision for both features was significantly enhanced when task-irrelevant features were removed, but knowledge of which features would be probed provided no advantage over having to memorise both features of all items. In a second experiment, we assessed the effect of an interpolated orientation- or color-matching task on recall of orientations in a memory array. The presence of orientation information in the second array was found to disrupt memory of the first array. This cost in recall precision was identical whether the interfering features had to be remembered, attended to, or could be ignored, implying involuntary storage of behaviorally-irrelevant visual features. Together, these results indicate that merely attending to an object can promote automatic encoding of all its features, depleting limited working memory resources.

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43.435 Central attentional limitations in visual short-term memory retrieval

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A common finding in visual short-term memory tasks is a linear increase in reaction time with the increase in memory load. The RT function is assumed to reflect memory search processes during the retrieval phase of the short-term memory task. Using the PRP dual task paradigm, the present study examined whether central attention is involved in memory search during retrieval. Following previous suggestions that qualitatively different processes occur in VSTM tasks with short and longer delay periods, the involvement of central attention in retrieval was examined separately for short and long delays. Two groups of participants performed a color short-term memory task, one group with a short delay period of 1.5 seconds, and the second group with a longer delay period of 6 seconds. The load was varied between one and three items. During the retrieval phase of the memory task, participants performed a secondary tone discrimination task that occupied central attention while they were searching through the memory set. The results showed a dissociation between short and long delays. The occurrence of the concurrent tone discrimination task had no impact on retrieval processes in the short delay condition, but led to the postponement of retrieval processes in the long delay condition. Taken together, the experiments provide evidence that central attention is involved in retrieval processes, only when items are maintained for longer periods, and emphasize further the qualitative distinction between VSTM tasks with short and long delays.

43.436 Implicit processing of labels facilitates the formation of compressed working memory representations

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We can only hold a limited amount of information in visual working memory. However, when there are strong regularities in the visual input, information can be encoded in a more compressed fashion and better remembered (Brady, Konkle, & Alvarez, 2009). In the present investigation, we ask how giving names to these regularities could increase this advantage. Labels help young infants individuate objects (Xu, 2002), and while previous research has focused on in what context language may affect visual representations, little work elucidates the mechanisms by which labels affect how we encode and remember novel information. In this experiment, observers were presented with four color pair objects for 2 seconds, and then were probed after a 1 second delay on a single color from the display. Covariance was introduced so that some color pairs occurred more often than others (80% frequency). Observers in the 'label' group saw labels (e.g., wug) above each color pair during the first 7 out of 10 blocks (labels co-occurred 100% of the time), and observers in the control group received no labels at all. Initially, both groups of observers remembered an equal number of items, but observers who received labels above the color pairs remembered significantly more items from the display during blocks 2, 3, and 4 (2-tailed t-tests, all $p < .001$). For the rest of the experiment, observers in both groups remembered an equal number of items from the display (all $p > .05$). Thus, observers who received labels learned faster than those who did not receive labels. After completing the experiment, all but one participant in the label condition claimed to not have used them. These findings suggest that labels can implicitly facilitate the process of learning regularities and compressing redundant information to form more efficient memory representations.

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43.437 Effects of verbalization on repetition priming of faces

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Visual memory can be changed unlike photographs. One example of this imperfect nature of visual memory is verbal overshadowing effect; describing remembered faces impairs the recognition of the described faces (Meissner & Memon, 2002; Schooler & Engstler-Schooler, 1990). Unlike the results using a recognition task, Lloyd-Jones et al. (2006) found that verbalization did not impair visual memory when a priming task was used. However, verbalization might modulate the amount of priming if the processing mode of a priming task is not matched to the one in verbalization, because inappropriate mode is one of the major reasons for verbal overshadowing (Macrae & Lewis, 2002; Schooler, 2002). We tested this hypothesis using a full factorial design. Specifically, we varied the types of verbalization - either feature-focused or global descriptions. We also modulated the types of stimuli in the priming task – either upright or inverted faces. Participants first studied 24 faces for 5 seconds each. Depending on each participant's assignment to the types of verbalization, they performed a different verbalization task for 5 minutes. After this procedure, all of them performed a gender discrimination task on the studied and new faces presented either upright or inverted. We calculated the effect of priming by subtracting reaction times to the studied faces from those to new faces. We found feature-focused description removed the effect of priming for upright faces, but not for inverted faces. On the contrary, global description removed the effect of priming for inverted faces, but not for upright faces. The results suggest that verbalization changes the amount of priming if the processing mode is not matched to the one needed to perform a task. In addition, visual representation is influenced by verbalization because the effect of priming depended on the types of verbalization.

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See page 3 for Abstract Numbering System

43.439 **On the Nature of Prototype Effects in Visual Working Memory for Motion**

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The characteristics of stimuli from previous trials can distort visual short-term memory for the current trial's stimulus (Huang & Sekuler, 2010; Kang, Hong, Blake, & Woodman, 2011). However, the degree to which prior information influences memory, and the variables that control reliance on this information remain unknown. In the current study, we explored prior information's influence on memory for briefly-viewed random dot cinematograms (RDCs). Subjects viewed RDCs at two levels of coherence (50 and 90%). Following each presentation, subjects used a cursor to indicate the overall direction in which the dots had moved. Within a block of trials, RDC directions were drawn randomly from a narrow distribution located within a particular quadrant. The distribution's central direction defined a block's prototype direction, which changed from block to block. Subjects' errors were sign corrected such that errors in the direction of the prototype stimulus (the block's mean direction) were positive, and those in the opposite direction were negative. The results revealed a prototype effect: errors were shifted toward the mean direction of motion within a given block of trials. We analyzed the time-course of errors within a block of trials in which the prototype (mean) direction was fixed. The prototype effect was limited to the low coherence RDCs, and was strongest early in a block, when the prototype direction was novel. When errors were scored relative to the mean direction of the immediately preceding block, no prototype effects were observed. These results are inconsistent with an account in which all previous trials are equally-weighted in computing priors for visual motion (Morgan, Watamaniuk, & McKee, 2000). A simple model incorporating the idea that reliance on prior information is strongest in the face of uncertainty about the contents of memory provides a good account of the critical data.

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43.440 **Accurately modeling Visual Working Memory performance at the individual trial level**

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Visual Working Memory (VWM) performance may emerge from factors such as the likelihood that a given item has been processed (Pm) and the resolution of stored representations (SD). Recent approaches to modeling VWM have assumed that, when an item is not processed (i.e., Pm=0), observers' guesses will be uniform – but the actual pattern of guesses was not measured. And, has assumed that internal representations are subject to Gaussian noise (SD) that is constant across various feature values – but this constancy was not empirically tested. These assumptions make generalization difficult when guesses are not uniform (e.g., biased guessing) and when internal noise varies as a function of the parameter value (e.g., scalar variability in numerosity; Whalen, 1999; oblique effect in orientation; Appelle, 1972). Here we demonstrate a general-purpose approach to modeling performance in VWM tasks that includes: 1) empirically measuring guesses on trials with 0ms-stimulus-duration, 2) generating appropriate models of internal representation for particular feature dimensions, and 3) iteratively generating mixture models to estimate a likelihood that each observation derives from an internal representation. In three experiments, we use this method to estimate Pm and SD for color, orientation, and numerosity of arrays of 1, 3, or 6 sets at stimulus duration of 0, 33, 67, 100, 133, or 198ms. Results show that Pm increases from 0 to 100ms then attains asymptote while SD remains stable across all SOA's, suggesting that information accumulation in perception completes within 100ms and that stored information in VWM is all-or-none. SD remained constant across set sizes, favoring a fixed-resolution model of VWM. This approach embraces and extends previous modeling efforts, allowing us to empirically estimate guessing, capture a wider range of appropriate models for internal representations, and analyze data at the individual trial level.

43.441 **On successive memories**

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Once having reproduced from memory a stimulus-feature (the standard) and in the presence of this reproduction, is a subsequent decision on a probe being identical to or different from the standard made exclusively with respect to this reproduction, or is it also based on information not used during the reproduction task? If the latter, what's the nature of this information? A randomly oriented 1.5 cpd Gabor (the standard) was briefly (200 ms) presented on one side of fixation. Observers then attempted to reproduce its orientation (S) by rotating another Gabor (the match), subsequently presented on the opposite side of fixation. Once satisfied with the match's orientation (M) that remained visible, they were presented at the location of the standard with a probe Gabor whose orientation (P) was either identical with (50% of trials) or different from S by one of 5 ΔS values held constant within each block of trials. Observers had to decide whether P=S ('Same') or P≠S ('Different'). 'Same'/'Different' judgments in this latter task were largely determined by the difference between P and M. However, for any given P-M difference the frequency of 'Same' responses was larger on P=S than on P≠S trials. A model where the trial-by-trial decision criterion is inversely proportional to observer's confidence in his match (i.e. proportional to the memory noise), predicts well the observed performances. It implies trial-by-trial (introspective) knowledge of a non-static memory noise (s). Observers modulate their decision criteria according to their trial-by-trial confidence (proportional to memory noise). This translates into adopting a more conservative criterion on trials where Probe ≠ Standard than on those where Probe = Standard. These criterial shifts can be observed only by reference to the Match; they remain immaterial in a standard Y/N experiment.

Color and light: Surfaces and materials

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

43.442 **Influence of bright surrounding colors appearing in the illuminant-mode on color constancy**

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Human visual system accomplishes color constancy by discounting an illuminant color, which is estimated with luminances and chromaticities of surrounding colors (e.g. Golz & MacLeod, 2002). It was shown that the brighter surrounding colors had greater contribution to estimation of illuminant color than dimmer colors (Uchikawa et al., in press). However, bright colors in a scene do not necessarily carry information about scene illuminant since there might be some light sources in the scene. The question here is whether the visual system can successfully ignore such surrounding colors appearing in the illuminant-mode to accomplish color constancy. We conducted experiments with the surrounding stimuli that were made to be either in the surface-mode or in the illuminant-mode being independent of their luminances and chromaticities. The stimulus was composed of 60 surrounding hexagons of R, G, B bright and dim colors (1) without gap between neighbor hexagons, (2) with black gap, and (3) with three black segments on each hexagon to be perceived as volumetric cubes. Observers performed achromatic setting (paper match) of the central test patch and evaluated color appearance mode of the brightest surrounding color. The results showed the subjective achromatic points differed among the three stimulus types having the same luminance and chromaticity of surrounding colors. This indicates that, in addition to the luminance balance of surrounding colors, the appearance of surrounding colors have influence on color constancy.

43.443 **Differential Processing of Material and Object Images: Evidence from ERP Recordings**

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It has been recently proposed on the basis of psychophysical experiments that material categorization is less efficient than object categorization (Wiebel, Valsecchi & Gegenfurtner, VSS 2011). Here we set out to find electrophysiological evidence for the differential processing of material and object images measuring ERPs while subjects performed a Go/NoGo task on either material images (wood vs. stone) or object images (people vs. animals). Each of the four categories was used as a target and as a nontarget in eight alternating sessions. For each category we presented 80 images.

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Mean luminance and contrast were normalized. Object images were from the COREL database, whereas material images were taken by ourselves. The subject's task was to press a button as fast as possible if the image belonged to the target category and to suppress any response otherwise. The results showed that in line with previous findings, subjects responded significantly slower on material trials compared to objects trials (Adelson, Sharan & Rosenholtz, VSS 2011). Besides, the target effect (Go minus NoGo activity at frontal sites) which had been described for objects (Johnson & Olshausen, JOV 2003) was extended to materials. Furthermore, using a linear classifier we were able to decode each specific category independent of its target- status based on the spatial pattern of the ERPs. Go vs. NoGo trials could also be classified above chance. Crucially, we managed to classify material and object images as early as 110ms. Moreover, at this point in time we found the spatial distribution of weights assigned to each electrode in the material vs. object classification to be similar for Go and NoGo trials. This suggests differential processing of the low-level properties of material and object images independent of their target status very early in time.

43.444 **Perceptual information about surface qualities used in material discrimination**

Yusuke Tani[1](tani@vpac.cs.tut.ac.jp), Toshiki Matsushima[1], Takehiro Nagai[1], Kowa Koida[2], Michiteru Kitazaki[1], Shigeki Nakauchi[1]; [1]Computer Science and Engineering, Toyohashi University of Technology, [2]Electronics Inspired-Interdisciplinary Research Institute, Toyohashi University of Technology

Material surfaces have enormous visual information regarding their qualities. On the other hand, human observers can recognize material categories at a glance. This suggests that the human visual system can immediately extract small but enough amount of information to perceive material categories. To investigate the pieces of information that support the material perception, we conducted two experiments about surface quality evaluation and material discrimination. The stimuli were presented on a gamma-corrected CRT display. They were photographs of the real material samples we prepared. The samples were size- and shape-controlled fabrics, glasses, leathers, metals, plastics, stones, and woods. More than ten samples (11 to 13) were prepared for each material. In Experiment 1, participants observed the stimulus and evaluated nine material features, which were both visual and non-visual, such as glossiness, transparency, roughness and so on. In Experiment 2, two photographs were presented simultaneously, and the task was to answer whether they belonged to the same material category or not, as quickly as possible. Multi-dimensional scaling applied to the results of Experiment 1 suggested that the nine material features can be represented by about three components. Multi regression analysis applied to the results of Experiment 2 suggested that the reaction time can be explained mostly by three components almost the same as those of Experiment 1. At the same time, both analyses showed that all the nine features contributed to the material categorization. It was also suggested that not only visual features but also non-visual features contribute to the discrimination of material category. On the other hand, our analyses also revealed that other material features in addition to the nine features should be introduced to explain the reaction time for material discrimination.

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43.445 **Luminance Constrains Colour Edge Information**

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There is anecdotal evidence that luminance dominates chromatic information in the perception of edges. As a result, a blurred chromatic edge appears less so when overlaid on a sharp luminance edge. This effect has not been quantified and may be caused by lower chromatic acuity or by differences in contrast or spatial frequency content between the channels, rather than a mechanism which is particularly sensitive to luminance edges. We investigated this in a series of experiments in which the chromatic and luminance components of photographic images were separated and Gaussian blurred to varying degrees in accordance with a staircase procedure. A two-interval-forced-choice procedure was used to measure participants' blur detection thresholds for each channel (colour and luminance) with and without its sharp counterpart. Acuity for chromatic blur was poorer in general and reduced further in the presence of sharp luminance information. However, luminance blur thresholds were unaffected by the presence of sharp chromatic information. These findings remained robust even when the contrast of the channels was equated. Natural images contain more high spatial-frequency luminance information than chromatic. To investigate whether this was responsible for the effect we reversed the colour and luminance channels. The images were converted into MB-DKL space (Derrington, Krauskopf, & Lennie, 1984; Macleod & Boynton, 1979) and the LM and S channels were replaced with the luminance information and the luminance channel was replaced with half of the sum of the LM and S channels. Chromatic blur thresholds were then no longer poorer in general, but chromatic blur was still masked by luminance information and there was again no effect of chromatic information on luminance blur thresholds. It appears that the masking effect is specific to the luminance channel, suggesting that luminance information about edges is automatically used by the visual system in preference to colour.

Acknowledgement: EPSRC

43.446 **Eye movements reveal inter-observer processing differences in a color appearance task**

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In color constancy experiments, observers typically judge surface appearance across an illumination change. Performance in such tasks can be modulated by experimental instructions (e.g., Arend & Reeves, 1986), but the nature of the processes mediating these instructional effects remains unclear. We ask whether eye movements made during a color appearance task provide insight into the underlying processing. On each trial, observers fixated on a color target (3.1° square) presented against a colored background. The background consisted of a simulation of many small illuminated Munsell papers. After one second, the target was replaced by four comparison squares, each 3.1° and located 8.2° eccentric from the fixation point. On illuminant-change trials, the simulated illuminant of the background changed when the comparison squares were presented. On control trials the background remained constant throughout the trial. Three observers were instructed to choose the comparison square from which the light reaching their eye was most similar to the target (spectral-match instructions). Four different observers were instructed to choose the square that appeared to be cut from the same piece of paper as the target (reflectance-match instructions). Observers used a mouse to click on a chosen square. The comparison squares always included both a spectral match and a reflectance match to the target. Observer eye movements were monitored. On the illuminant-change trials, five observers tended to choose the spectral match, and this choice correlated with the comparison square to which they first fixated. Two observers, both of whom were given reflectance-match instructions, tended to choose the reflectance match on most illuminant-change trails. Interestingly, these observers initially often fixated on the spectral match, but during the trial looked increasingly at the reflectance match. We tentatively interpret this dissociation between initial fixation and final choice as revealing an inter-observer difference in the processing used to accomplish the task.

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43.447 **Luminance Information Suffices to Model Vegetable Freshness Perception**

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Freshness perception is a quality discrimination process that influences our consumer choice and eating behaviour, especially of fresh products such as vegetables. Moreover, several of the most relevant sensory attributes influencing consumer perception of freshness are related with vision. To investigate which visual cues command the freshness perception in vegetables, we recorded the luminance and chromatic information of the freshness degradation process of four different vegetables (cabbage, strawberry, carrot and spinach) in a temperature, humidity and light controlled environment using a 2D luminance and chromaticity analyzer (TOPCON UA1000). Then, using a color management system to guarantee the exact reproduction of the recorded luminance and chromatic data, we created color and grayscale version of the stimuli. Then, we randomly presented those pictures to subjects who had to rate their perceived freshness using a visual analogue scale. The achromatic results did not differ from the chromatic ones suggesting that color information is not a determinant factor involved in our freshness perception. Furthermore, the results of the freshness perception were highly correlated with image and sub-band statistical measures of the luminance distribution in the images. Additionally, we digitally manipulated the original images of the cabbage stimuli only by modifying their

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luminance distribution and keeping intact their colour information. When we presented the resulting images, using the same psychophysical experimental setting, the subject's results showed that the perceived freshness also changed concordantly with the changes of the skewness of the luminance distribution. These results support the hypothesis that the freshness perception of vegetables is highly influenced by the luminance distribution present in that food texture. These findings not only can help represent a way to understand cognitive quality measurements which can be related closely to human perception but also design implementations of automatic food freshness estimators for the food industry.

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43.448 **Influence of complexity and memory color on naturalness judgments in color rendering**

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Naturalness judgments in color rendering of complex scenes indicate that observers require illuminants with correlated color temperatures (CCT) around 7000K. Here we investigated the influence of the complexity and memory color on these judgments. Fifteen images of commercial food counters of fruits, vegetables, meat, and fish were digitalized by a hyperspectral system. The scenes were simulated as if they were rendered by illuminants synthesized from Judd's daylight spectral basis functions for a grid of chromaticities on and around the Planckian locus with CCT ranging 2,222 – 20,000K and were displayed on an LCD monitor controlled by a ViSaGe system. The task of the observer was always to adjust the color of the illumination to produce the most natural appearance of the test object. In condition A, the test object was a part of an object selected from a scene. In condition B, the test object was the same but 70% the pixels were spatially randomized. To make sure that in A and B the observers recognized the test object the complete scene was shown to the observer beforehand each adjustment trial. Condition C was similar to B except that the observers did not see the full scene and therefore did not recognize the object. The background of the test object was always the average of the complex scene. One group of observers tested conditions A and B and a different group tested condition C. In A and B conditions the average CCT obtained was considerably lower than that obtained for the complex scenes: for A was 6100K and for B was 6500K. For condition C even lower CCT was obtained, about 5000K. These results show that both the complexity and the memory color of the objects have a considerable influence in the judgments of naturalness of the illumination.

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43.449 **Perceptual matching of translucent materials under different illuminant conditions.**

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INTRODUCTION: Many common materials such as food or human skin have translucent properties and human observers can easily distinguish them from opaque materials. Even when physical translucency of the material is identical, its perceptual translucency is largely affected by illuminant conditions in a complex way because of sub-surface scattering. This study investigates how the illuminant conditions alter the perceptual translucency by a simple matching experiment with translucent materials under two different illuminant conditions. METHODS: Bottle-shaped objects made from translucent material (polyethylene terephthalate: PET) were used in the experiment. Physical translucency of the bottles was varied in five levels by mixing white coloring agent of 0.25, 0.5, 1.0, 1.7 and 2.5%. Observers were presented simultaneously with a bottle as a test, which was illuminated both from the front and the back, and with all of the five bottles in a standard light booth with a D65 light source as reference stimuli. The observers were instructed to answer which one in the five reference bottles seemed to be most similar to the test bottle. The test bottle was randomly chosen from the five different bottles, and the intensity of the illuminant behind the test bottle (backlight) was varied in five levels. Thus, matching was performed under 25 conditions in total. RESULTS & CONCLUSIONS: Perceptual translucency of the test bottles was affected with physical translucency of the bottle as expected. Intensity of the backlight also altered the perceptual translucency but not straightforwardly: perceptual translucency did not monotonically increase with the backlight intensity. While RMS contrasts of the test bottle images without highlight regions could well explain the dependency of perceptual translucency both on the physical translucency and the backlight intensity. This supports the view that RMS contrast of non-specular shading is an image cue for matching perceptual translucency.

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43.450 **Extraction of CG image regions contributing to translucency perception using a psychophysical reverse correlation method**

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Image characteristics in a 3D object contributing to the translucent perception is an interesting issue in understanding material perception. While Motoyoshi (2010) suggested a global cue in an object image for the translucency perception, the spatial contrast relationship between non-specular and specular components, local cues for the translucency perception have rarely been investigated. Here we intended to extract spatial regions related to the translucency perception for a CG object image with a psychophysical reverse correlation method. The stimulus was an image created by combining two CG images based on a two-dimensional random pattern, which caused a difference in perceptual translucency between multiple stimuli made from identical CG images. The observers simultaneously viewed two stimuli created based on different composition patterns, and judged which stimulus had stronger translucency. The composition patterns were averaged across all the trials in each of the two classes defined by the observer responses (more- and less-translucent). The difference pattern between the averaged patterns for the two classes was defined as a "translucency-related pattern". The translucency-related patterns exhibited statistically significant spatial variations, suggesting that the observers judged the translucency of the images more strongly based on particular spatial regions. The images created in the same manner as our composition stimuli based on the translucency-related patterns as composition patterns had smaller global contrasts of non-specular components than the images based on the reversed patterns of the translucency-related patterns, suggesting the relationship between the translucency and global image contrasts. Meanwhile, in the original CG images, the local luminance contrasts in the image regions that were significantly related to the translucency judgment and in the other regions were not significantly different. These results suggest that the observers judged the translucency of the CG images based on their global contrasts of non-specular components, but not on their local contrasts.

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43.451 **Binocular cues for glossiness**

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The disparity fields created by matte surfaces match the surface's true depth profile. However, for specular surfaces the disparities are shifted away from the surface, tracing out virtual ('adanaclastic') surfaces in depth. Previous studies (Blake & Bülthoff, 1990, Nature, 343, 165; Wendt et al, 2008, doi:10.1167/8.1.14) showed that surfaces appear glossier and more realistic if highlight disparities are physically correct. But which specific binocular cues does the visual system use to identify specularities? We computationally analyzed disparity fields generated by irregularly-shaped Lambertian and purely specular objects and found several important differences: 1) the adanaclastic surface is piecewise smooth, but with major discontinuities near inflection points of the physical surface, where disparities go to infinity. Such patches are separated by non-fusible regions which appear aniseikonic. 2) Statistics of vertical disparities (VD) and horizontal disparity gradients (HDG) of specular objects are qualitatively different from Lambertian surfaces. For specular surfaces, the distributions are heavy-tailed, containing large values that often exceed fusibility limits. This suggests specific binocular cues that the visual system could use for distinguishing specular and Lambertian surfaces. In order to test whether these disparity cues affect perceived glossiness, we developed stimuli that allow us to vary disparity fields continuously from perfectly specular (vIPD = 1) to matte (vIPD = 0) and beyond to 'super glossy' (vIPD = -1) by varying a single parameter ('virtual IPD'). Crucially, stimuli from the interval (vIPD

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= [0,-1]) were quantitatively different from true specular materials, but their disparity fields exhibiting the aforementioned discontinuities and extreme VDs and HDGs. We measured gloss discrimination (N = 5) and found that above (vIPD = 0.6) human observers perceived stimuli to be as glossy as physically correct mirror stimuli (vIPD=1). This suggests the brain does not 'know the physics of specular reflection' but instead relies on specific binocular cues.

43.452 **Colour constancy measured via partial hue matching**

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Colour constancy is usually measured by the asymmetric colour matching technique which implies changing the surface reflectivity that is hard to implement. Furthermore, an exact match of two surfaces lit by different lights is, actually, impossible to achieve. We use a new method (partial hue matching) which is free of these disadvantages. It aims at describing colour appearance in terms of component hues. Since Hering's time each hue is believed to be made up of the four component hues (yellow, blue, red and green). A hue consisting of just one component hue is called unitary (or unique). The partial hue-matching technique has been used to reveal the component and unitary hues for a sample of 32 Munsell papers, where illuminated by neutral, yellow, blue, green and red light and assessed by four normal trichromatic observers. The same set of four component hues has been found under both the neutral and the chromatic illuminations for all of the observers. On average, more than 87% of the papers containing a particular component hue under the neutral illumination also have this component hue when lit by the chromatic lights. However, only a quarter of the papers perceived as unitary under the neutral illumination continue being perceived as unitary under all of the chromatic illuminations. In other words, most unitary colours shift along the hue circle due to change in an illuminant's chromaticity. Still, this unitary colour shift is relatively small: on average it does not exceed one Munsell Hue step. Therefore, that although the colour appearance of Munsell papers changed with illumination, the component hue content of each paper remained relatively unaltered considering changes in illumination. Thus, the partial hue matching technique seems to have revealed rather high colour constancy.

43.453 **The role of dynamic visual information in the estimation of liquid viscosity**

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Humans can judge liquid viscosity using only visual information. For example, honey is 'thick' (i.e. high viscosity), while water is 'thin' (low viscosity). Even though this sort of liquid viscosity estimation is mundane, vision science has not addressed what image processing underlies the estimation. The purpose of this study was to examine visual factors enabling us to estimate liquid viscosity, focusing on dynamic visual information. We employed the Blender physics engine to simulate kinetic viscosity of liquids, and created 50 movies (ten scenes each with five kinematic viscosities). The observers were asked to watch each of the movies, and subjectively rate liquid viscosity We first confirmed that the rated viscosity increased nearly in proportion to the simulated kinematic viscosity. To examine how simulated viscosity was related to the speed of liquid flow, we computed optical flow of liquid flow. The histogram of the speed of motion signals indicated that a liquid flow with a lower kinetic viscosity tends to have a higher overall speed. To examine the effect of overall speed of liquid flow on viscosity rating, we manipulated frame duration of each movie, and found that the rated viscosity increased with the frame duration. To investigate the importance of the spatial pattern of motion speed, we divided a movie into an array of cells (each of the cells was windowed by a tapered cosine circular function), and randomized image orientation within each cell (direction scramble), or shuffled the positions of cells (position scramble). Viscosity rating was generally unchanged when the stimuli were scrambled in these ways. However, when the cell size was small, scrambling position decreased the correlation between observers' viscosity rating and simulated viscosity. The results indicate that in estimating liquid viscosity the visual system makes use of motion speed distribution.

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43.454 **Visual adaptation to reflectance-specific image motion**

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Recently, we described several surface reflectance-specific motion characteristics that the visual system may use to determine whether a rotating object appears shiny or matte (Doerschner et al., 2011). We used an adaptation paradigm to test whether there exist neuronal populations that are sensitive to such reflectance-specific image motion characteristics. Stimuli were computer-rendered movies of 5 unfamiliar, rotating objects. Eleven stickiness levels for each object were created by morphing between 'sticky' (diffusely reflecting) and 'slipping' (100% specularly reflecting) renderings of a given object with different mixing values, resulting in a total of 55 movies. For familiarization purposes observers were first shown a sequence of movies of an object transitioning from sticky to slipping though all 11 levels. In the pre-test observers rated the apparent shininess for each movie on a scale from 1 (very matte) to 5 (very shiny). The order of presentation was randomized. During adaptation, observers first adapted to a sticky movie for 120 s. This was then followed by a 2 s test in which observers rated shininess. Every fifth trial was preceded by a 24 s top-up adaptation period. Importantly, in order to prevent low-level motion adaptation we randomly selected a new rotation axis (out of 6) for each 2 s interval for the adaptor during adaptation periods. We compared the shininess ratings of all movies in pre-, and post-test. Overall, we found that, across observers and objects, adaptation to a sticky movie significantly affected the perceived shininess of subsequent stimuli (All observers: $F(1,1098)=10.4781$ $p<0.002$). Post-hoc analysis revealed that an increase in perceived shininess occurred mainly at higher levels of stickiness. These results support the notion of cortical mechanisms sensitive to reflectance-specific image motion patterns.

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43.455 **Through a glass brightly: seeing beyond the surface in image quality**

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Images have always presented a puzzle for perceptual scientists because they serve as visual representations of objects while also being objects themselves. Much effort has gone toward understanding how images represent the three-dimensional properties of objects, and there is now some understanding of the relations between the geometric projections used in image rendering and the perceived shapes of depicted objects. Considerably less effort has focused on how images convey other properties of objects such as material properties and textures, though there is a vast literature on image quality that purports to speak to these issues. The premise of this project is that much of the work on image quality is misguided because it conflates the properties of images as signals with the properties of images as visual representations. In a series of experiments we have investigated the ability of conventionally low quality (noisy, low contrast, blurry) images to faithfully represent the material properties of objects. Contrary to the predictions of standard image quality metrics, we find that the ability of these images to faithfully represent material properties, as measured by Thurstonian scaling, is not much reduced by these distortions. It is as if observers are able to see through the image plane distortions to correctly perceive the material properties of the depicted objects. On the basis of these experiments we are developing new image quality metrics that take into account recent findings on the role of light reflection statistics in material perception, and analyze interactions between the statistics of light structuring by materials and the statistics of image coding distortions, to better predict how well images with different signal properties serve as visual representations of the objects they depict.

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43.456 **Scotopic hue percepts in natural scenes**

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The color appearance of an object under scotopic illuminating conditions varies depending on the context. Objects generally appear bluish-green when viewed in isolation, but can appear red or orange when seen with another object in view (Pokorny et al., 2006). The perceived hue of a test ring viewed under scotopic light levels changes with contrast, number, and spacing of inducer rings (Elliott & Cao, VSS2010). This study explored if 1) relational scotopic hue percepts occur in natural scenes and 2) whether hue percepts depend on contrast and spatial frequency relations within the images. Twenty-four natural images were chosen from the McGill Calibrated Colour Image Database. The images were calibrated and presented using only the B phosphor of a CRT (subtending 24°, mean luminance of -3.89 log photopic or -3.13 scotopic cd/m2). Following 25 min of dark adaptation, ten observers reported perceived hue and saturation using a hue scaling method for a 4° region (selected to highlight specific objects or uniform regions). Hue percepts were reported in 29% to 96% of the trials, depending on the image. The magnitude and polarity of contrast between the region and mean image luminance played a large role in reported hues. Hue percepts were reported more often for images with a mean contrast magnitude >14% within the region compared to images with a mean region contrast magnitude ≤14%. Reddish [yellowish] hues were reported only when region contrast was lower [higher] than the mean image luminance, which shows clear support for relational hues percepts in natural scenes. Memory color also contributed to hue percepts for some images, in which the object was clearly identifiable and had a strong daylight color associated with it. The role of spatial frequency content was unclear due to variability in the amplitude spectra across images.

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43.457 **Glossiness of layered materials**

Peter Vangorp[1](peter.vangorp@psychol.uni-giessen.de), Roland W. Fleming[1]; [1]Justus-Liebig-University Giessen

Most previous work on gloss perception has examined the strength, and to some extent the spread (roughness), of the specular lobe in simple single-layered BRDFs. However BRDFs can be substantially more complex than this and it is interesting to ask how many additional perceptual dimensions there could be in the visual representation of surface reflectance qualities. To address this, we tested two-layered materials such as glossy plastics coated with a thin layer of varnish. Stimuli were renderings of irregularly-shaped objects under environment illumination, with either one Ward specular BRDF layer, or two such layers, with the same total specular reflectance but different roughness parameters. This creates both sharp and broad highlights simultaneously. Three differently-shaped objects were presented side by side: the target two-layered material in the middle, a single-layered approximation on one side, and the same two-layered material on the other. The two-layered materials were characterized by the average and difference of their Ward roughness parameters. The single-layered approximation used only the average Ward roughness parameter. This parameter was previously shown to be approximately perceptually linear. Subjects chose which material looked most similar to the target material in a 2AFC task. Within each block of the same average roughness parameter, a Quest staircase procedure was used to select the next pair of roughness values. Our results show that subjects do indeed discriminate between single-layered and two-layered materials when the difference between the two roughness parameters exceeds a certain threshold. This suggests that layers of glossy materials may be represented as orthogonal dimensions of gloss perception. It is however unclear whether more than two layers of gloss can still be discriminated. There is also evidence that the discrimination threshold depends on the average roughness parameter. Other possible factors include the diffuse and specular reflectance(s).

43.458 **Cone contrast magnitude and spatial arrangement affect color filling-in modes**

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Multiple color filling-in modes were reported in a complex stimulus [Hamburger et al, Vision Research(46), 1129-1138, 2006]. However, it is unclear what determines color filling-in modes. The current study investigated the role of spatial arrangement of cone contrasts among different areas in determining color filling-in modes. A 12°-16° annulus (A) was surrounded by a 12° inner circular field (I) and a 36.6°x27.4° rectangular outer field (O). The inner and outer fields had l chromaticities of 0.705, 0.665 or 0.625 with a constant s chromaticity of 1.0 (luminance=13 cd/m2), leading to 9 inner-outer chromaticity combinations. The annulus differed from the inner and outer fields in the l and/or s chromaticities and observers reported their percept changes during a 25-second steady fixation for each trial. Color spreading was more likely (>50% trials) to occur along the edge between two adjacent fields (O->A, I->A, or A->I) that had a smaller contrast than the other edge. When the l chromaticities in the three fields changed monotonically (I>A>O or O>A>I) without an s difference, the annulus was predominantly (>90% trials) filled with the outer color (O->A) or the inner color (I->A) within a few seconds, with ~1/3 of these trials followed by a subsequent color spreading into the whole screen. When there was an s difference between the annulus and the other two fields, the annulus color was more likely (>60% trials) to spread into the inner field (A->I), but it typically required more than 10 seconds to complete. For all color filling-in modes, a metric combining the cone contrasts along both edges was significantly correlated with the time-to-filling-in and the percept duration. These results indicated that color filling-in modes were affected by the relative magnitude and spatial arrangement of the cone contrasts along the edges in a complex stimulus.

Acknowledgement: R01EY019651

Perceptual organization: Grouping and segmentation

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

43.501 **Neuronal representation of subjective shapes in area V4**

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Subjective contours, or illusory contours, are a common tool to study neuronal mechanisms of perceptual completion in the visual system. Psychophysical investigations of subjective contours and shapes point toward an early integration of visual cues to form the illusory percept. Furthermore, recordings in monkeys have shown that subjective contours evoke spiking responses from neurons in areas V1 and V2. However, neuroimaging studies in humans suggest that the strongest percept-related responses to subjective contours are found in higher-tier visual areas compared to lower-tier visual areas. A possible explanation for this apparent confound is that early cortical responses to subjective contours are mediated by descending signals from higher level visual areas, such as shape-sensitive area V4. This idea is further supported by the finding that ablation of V4 in macaques results in selective impairment of subjective contour perception. Here we investigate single neuron responses in macaque area V4 to subjectively defined shapes. We conducted simultaneous multi-electrode recordings using a chronic 96-channel array in two fixating macaque monkeys. Stimuli included conventional subjective squares defined by four "pac-man" inducers with and without coloration, along with physically similar controls that did not induce perception of illusory surfaces. We sampled V4 neurons with a range of receptive field locations surrounding all four inducers. We found that V4 neurons exhibited increased responses for subjective stimuli compared to non-illusory controls in both monkeys. This effect was strongly enhanced if the central (illusory) surface of the subjective shape coincided with the center of the neuron's receptive field. These results suggest that neurons in area V4 might play a crucial role in integrating visual cues to perceptually complete objects.

Acknowledgement: Intramural Program of NIH

43.502 **Decoding global contour perception in the human visual cortex**

Shu-Guang Kuai[1](S.Kuai@bham.ac.uk), Alan Meeson[1], Zoe Kourtzi[1,2]; [1]School of Psychology, University of Birmingham, UK, [2]Laboratory for Neuro- and Psychophysiology, K. U. Leuven, Belgium

Successful recognition of objects in cluttered scenes entails the integration of discrete elements to global contours. Previous studies have implicated a range of visual areas in contour integration, from primary visual cortex to higher occipitotemporal regions. However, the precise contribution of each of these regions to the perception of global contours remains unclear. Here, we compared behavioral and fMRI measurements to test for visual areas that mediate global contour perception. We presented observers with contours comprising of collinear Gabor elements that were embedded in a background of randomly oriented Gabors. We manipulated parametrically contour salience by adding local orientation jitter (±0º, ±10º, ±15º, ±20º, ±30º, or ±45º) to the contour elements. In an event-related fMRI design, we asked observers to judge whether the stimulus presented in each trial contained contours or not. The behavioral results showed that observers' performance decreased sharply for local jitter between 15° and 30° rather than linearly with increasing jitter. We then compared these psychometric functions with fMR-metric functions computed using multi-voxel pattern analysis of fMRI signals in independently localized visual areas. In particular, we trained a linear SVM (support vector machine) classifier to predict whether the stimulus on each trial contained contours or not. We plotted the performance of the classifier across local orientation jitter for each visual area. Our findings showed close correspondence in human and classifier performance for higher occipitotemporal regions (V3B/KO, LO). In contrast, for early visual areas, classifier performance increased linearly with decreasing local orientation jitter. Our findings suggest that early visual areas may signal contour configurations based on local orientation distribution, while higher visual areas mediate the perception of global shape contours.

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43.503 **Detection of natural shapes in noise**

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We studied the detection of natural shapes embedded in random backgrounds. Detecting coherent objects in cluttered background is a basic function of perceptual organization. Numerous studies have investigated the case of simple open contours, but few have considered the more naturalistic case of complex closed shapes. We studied the detection of natural shapes (the bounding contours of animals and leaves drawn from several natural shape databases) embedded in random backgrounds. In previous work on open contours (VSS2011) we showed that detection performance falls off rapidly with contour complexity, quantified using an information-theoretic measure (cumulative surprisal, Feldman & Singh 2005). For closed contours (enclosing shaped regions), we generalize this complexity measure using the probabilistic shape-generating skeletal model of Feldman & Singh (2006), which provides a simple measure of global (region-based) shape complexity based on description length (DL) conditioned on the estimated skeletal model. In the tested displays, contours consisted of chains of pixels embedded in random monochromatic pixel noise. We evaluated proportion correct (2IFC) as a function of simple contour complexity (integrated surprisal along the contour), the new closed shape complexity measure (cumulative surprisal given the estimated skeletal model), and several conventional measures of global shape properties such as convexity and compactness. Performance degraded markedly with both contour complexity and the new measure of global shape complexity, falling to near chance levels as complexity approached purely random structure (maximum Kolmogorov complexity). The results suggest that both contour and region geometry play important roles in representing form.

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43.504 **Translation invariance with a contour integration task**

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We investigated the role of contour integration in a task that required observers to identify an object at different positions in the visual field. Our goal was to measure the ability to match shapes presented sequentially in different parts of the visual field (translation invariance) as a function of shape-element grouping. Contours consisted of seven discrete 'Gabor' elements that were either aligned to form a smooth path (aligned with the direction of the path) or a jagged path (randomly oriented with respect to the path). Observers were presented with smooth or jagged contours either side of the fixation point (2 deg, 4 deg, or 6 deg, to the left or right) for 250 ms. Following an ISI of 250 ms, a second contour was presented, also for 250 ms. For one half of the trials, the same contour was presented in both intervals; for the other, a small change was made to the contour path. Also, on half of the trials, both contours were presented in the same position, and on half the trials the second contour was presented in the opposite hemifield, resulting in a separation distance of 4 deg, 8 deg, and 12 deg. A staircase procedure estimated threshold. Our results show that the process of contour integration can significantly improve observers' ability to match paths (i.e., determine if they are the same of or different) across the visual field. Three control experiments demonstrated that this improvement is due to binding of the contour-elements, and not due to a local orientation process. Furthermore, we found that observers were quite accurate at matching paths across relatively large distances with only a small fall-off in performance with eccentricity. The results are discussed in the context of underlying processes involved in translation invariance.

Acknowledgement: Research Grant 80393 from Nanyang Technological University to Anthony Hayes

43.505 **Neural patterns of minimal bending as perceptual curve completion**

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Visual curve completion is a fundamental perceptual organization process which attracts studies in both biological and machine vision research. Recent studies suggested framing the completion process directly in the visual area where presumably a significant part of it occurs, namely, the primary visual cortex. It was hypothesized that the perceived completed curves are formed by V1 neural activation patterns that obey certain biological and/or physical energy criteria. Since a suitable mathematical abstraction for V1 is the tangent bundle space R^2 x S^1, such energy criteria of neural activation patterns can be conveniently explored via formal energies of curves in this space. While previously it has been suggested to investigate the energy determined by the mere number of active cells in the pattern (which amounts to the pattern that consumes the minimal energy, e.g., Ben-Yosef&Ben-Shahar 2010), here we suggest considering also the properties of horizontal connectivity in V1. We show that patterns in which similarity between consecutive links is optimized, may be abstracted as curves of minimum bending (or curvature) in the tangent bundle space (i.e., elastica in the tangent bundle). Putting into action this basic (and single) principle provides completion predictions that match many psychophysical findings. Perhaps the most interesting one is that information of boundary curvature at the point of occlusion is both necessary and significant for a completion solution, in accordance with old and recent empirical and theoretical reports (e.g., Takeichi 1995; Singh&Hoffman 1999; Singh&Fulvio 2005). Based on this principle, we implement a numerical shape completion algorithm which (to the best of our knowledge) is the first ever to explicitly use boundary curvature in addition to boundary orientation and position. We show various experimental results which demonstrate the advantage of using boundary curvature for predicting perceptual completions and contours in natural scenes.

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43.506 **Modeling Spatiotemporal Boundary Formation**

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Spatiotemporal Boundary Formation (SBF) is the formation of illusory boundaries and completed shapes from spatially separated, local element transformations (Shipley & Kellman, 1994, 1996). We tested a computational model of SBF based on a proof that local edge orientation and global motion could be derived from three non-collinear, sequential, local events (such as element disappearance, color change, local motion, or local orientation change). We hypothesized that due to noise in registration of key inputs, the ideal model would exceed human performance. In three experiments, we measured orientation discrimination thresholds for edges defined by SBF as a function of element quantity (Exp. 1), element density (Exp. 2) and rate of element change (Exp. 3). In all three experiments, black circular elements on a white background disappeared whenever they came into contact with an illusory edge and reappeared when the edge moved beyond. Human performance was inferior to the ideal model. We developed a more realistic model by incorporating two kinds of noise: noise in registration of the relative positions of the elements, and noise in the velocity of the virtual object. Estimates were obtained by fitting the model to data from one condition. The improved model predicted average thresholds with high precision in the first two experiments and not well in the third. We suspect that this is due to minor, but important differences in display generation across the experiments. The model produced estimates of edge orientation from the positions and rates of transformation of elements in the display for each trial. The model's threshold estimates were then derived by submitting these results to the same staircase procedure used for human observers. These results offer a plausible account of how local element changes are used by the visual system to produce object boundaries, shape and global motion in SBF.

43.507 **Tilt aftereffects with orientations defined by motion or subjective contours**

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We studied tilt aftereffects using orientations that were defined by different visual modalities in order to better understand visual cortical organization. Specifically, we used static subjective contours and motion trajectories to define orientations that served as adapting and test stimuli. All stimuli were presented in a circular aperture. Randomly oriented lines drawn inside a half circle with their terminators aligned precisely along one diameter of the circle produced a vivid subjective contour along this diameter. The motion stimuli were similarly generated, except that all line terminators were rounded, thereby weakening the subjective contour. The lines moved randomly but remained along the diameter, which defined motion trajectories. The adaptor was oriented at -15˚ (0˚ was vertical), was either static or in motion, and remained unchanged in a session. The test was either static or in motion, and was oriented either at ±1˚, ±2˚, ±3˚, or ±4˚. The adaptor was first shown for 64 sec, with each subsequent top-up for 3.2 sec. Each adaptor was followed by a 400 ms test stimulus. All 16 possible test stimuli were randomly sampled and counterbalanced. Subjects indicated whether the test was tilted left or right from 0˚. The subjective 0˚ was estimated as a PSE of a psychometric function. The baseline subjective 0˚ was similarly measured from trials without any adapting stimulus. Interestingly, for those subjects who showed the basic TAE with a static adaptor and static test, TAE was also found when the motion stimulus was either the adaptor, the test, or both. These results indicate that orientation adaptation is not necessarily restricted locally at, e.g., V2 or MT. The neural substrates of such orientation adaptations may therefore be multi-level.

43.508 **Edge co-alignment facilitates short-term perceptual memory of global form**

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Perceptual grouping mechanisms bind spatially local edge information into global contours during form perception and scene segmentation. Relative orientations of adjacent elements comprising a contour play an important role in these perceptual organization processes. For instance, the detectability of a contour embedded in a highly camouflaging background is facilitated by increasing co-alignment of adjacent elements comprising the contour. The present study concerns contour-defined forms that only become visible when cued (by onset, motion, color, etc.), and briefly remain visible after the cue has ended, but eventually disappear (become camouflaged). This type of form-based perceptual persistence exemplifies short-term memory of perceptual organization following the removal of initial binding cues. We studied the effect of inter-element alignment on the duration of form-based perceptual persistence using circular contours comprised of short line segments that were embedded in a background of randomly oriented line segments. The contours were visible when they first appeared (onset acted as a cue) but always disappeared (became camouflaged) within a few seconds. We varied element co-alignment (co-circular versus random), inter-element distance (of contour and background elements) and the size of the circles these elements formed. Observers indicated when a circle was no longer visible. We found that circles comprised of co-circular elements persisted longer (took longer to disappear) than equally sized circles comprised of randomly oriented elements equated for position. We also observed an effect of contour and background density such that relatively dense circles persisted longest. Our results are consistent with perceptual grouping models that predict increasing contour visibility (detectability) as a function of increasing inter-element alignment and decreasing distance, even though the contours we used were not visible unless cued. We conclude that contour grouping and the perceptual persistence of global form reflect the operation of common neural mechanisms, and that form-based memory promotes sustained perceptual grouping.

43.509 **Motion direction and temporal frequency tuning of texture-surround capture of contour-shape**

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Aim: Contour-shape processing is selective to motion direction [Gheorghiu, Kingdom & Varshney, 2010, Journal of Vision, 10(3):18, 1-19), and surround textures prevent the shape of a contour from being processed as a contour but instead as part of a texture, a phenomenon we term here 'texture-surround capture of contour-shape' [Gheorghiu & Kingdom, 2011, Journal of Vision 11(11), 1038; Kingdom & Prins, 2009, Neuroreport, 20(1), 5-8]. This raises the question as to whether the effect of texture surrounds on contour shape processing is selective to motion direction and temporal frequency. Methods: Subjects adapted to pairs of sinusoidal-shaped textures or to single contours that differed in shape-frequency, and the resulting shifts in the apparent shape-frequency of single-contour test pairs was measured. The texture adaptors consisted of a central contour, and a non-overlapping surround made of a series of contours arranged in parallel. Contours drifted within a fixed stimulus window in one or other direction of their axis of shape modulation. We varied (i) motion direction and (ii) the temporal frequencies of both central contour and texture surround. Results: We found that (i) the shape after-effect was strongly reduced by surround textures moving in the same but not opposite directions to the central contour; (ii) the reduction in shape after-effect caused by the surround texture increased in magnitude with the temporal frequency of the central contour, and (iii) the reduction in shape after-effect was selective for same center-surround temporal frequency. Conclusion: Texture-surround capture of contour shape is tuned to both motion direction and temporal frequency.

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43.510 **Effects of contrast on spatial and temporal integration in 2D shape perception from dynamic occlusion**

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In self-motion, research has shown that optic flow can be a source that supplies essential information about heading, speed, and characteristics of the surrounding environment. Evidence has shown that increases in optic flow quality and quantity have additive effects on steering performance. Further, studies have shown that spatial integration (e.g., stimuli density) and temporal integration (e.g., stimuli lifetime) may play a key role in motion perception. In the current study, we examined how spatial and temporal integration are affected by the quality of optic flow in generating 2-D shape perception. Participants were asked to identify a 2D shape resulting from kinetic occlusion information. Displays consisted of 2D arrays of dots forming both foreground objects and the background texture. When the foreground object moves the disappearance and reappearance of back ground dots can be used to recover the object shape. Three experiments were conducted in which optic flow density, display contrast, and optic flow lifetime

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were variables of interest. In each of the three experiments, the threshold of one variable was measured, using a four-alternative forced choice staircase, while the other two variables were manipulated. In experiment 1, optical flow density threshold was measured for 8 participants using a 2 (contrast) by 2 (lifetime) within-subjects design; in experiment 2, contrast threshold was measured for 5 participants using a 3 (density) by 3 (lifetime) within-subjects design; in experiment 3, lifetime threshold was measured for 5 participants using a 3 (density) by 3 (contrast) within-subjects design. The results showed the performance in 2D shape perception decreased as a function of decreased contrast, decreased lifetime, and decreased density. These results suggest the spatial and temporal integration might be potential predictors of driving performance under low contrast conditions.

43.511 **Emergent features in object detection**

Matthew Inverso[1,2](matthew.inverso@gmail.com), John Wilder[1,2], Jacob Feldman[1,2], Manish Singh[1,2]; [1]Department of Psychology, Rutgers University, [2]Rutgers University Center for Cognitive Sciences

Detection of simple isolated contours amid random background elements is a basic perceptual capacity, and has been extensively studied. But while simple contours are essential building blocks of object representations, objects and scenes also involve emergent or “Gestalt” configural features that involve nonlocal combinations of contours. Here we investigate how such emergent features contribute to object detection. We constructed target objects from pairs of simple contours in various spatial relationships, and manipulated both the structure of the individual contours as well as the angle between the two contours -- a simple example of an emergent relational feature. The targets were embedded in grayscale pixel noise fields and subjects were asked to detect them, in a both an accuracy paradigm (2IFC, Exp. 1) and a response latency paradigm (2AFC, Exp. 2). In previous studies in our lab (Wilder, Feldman & Singh, VSS 2011) we demonstrated a strong influence of the complexity of individual contours on detectability, where complexity is quantified via the description length (DL) of the contour, defined as the cumulative surprisal (-log p) of the sequence of turning angles that make it up. In the current studies, we again find a strong effect of the complexity of the individual contours. But here we also find an independent effect of the angle between the two contours, with enhanced performance at both parallel (0 deg) and perpendicular (90 deg) configurations, and depressed performance at intermediate angles. This effect can be incorporated directly into the complexity formulation simply by adopting a mixture prior over the inter-contour angle and adding its surprisal to the DL of the ensemble. These results contribute to a more complete understanding of the how local and global features are integrated into object representations.

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43.512 **Revealing the Temporal Dynamics of Competitive Interactions in Figure-Ground Perception**

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Figure-ground perception is determined through competitive interactions. Convex regions are more likely to appear as objects (figures) than abutting concave regions, but context modulates this likelihood: In 100-ms displays, convex regions are increasingly likely to be seen as figures as the number of alternating convex and concave regions increases from 2 to 8 (57% - 89%; Peterson & Salvagio, 2008). These convexity-concatenation effects (CCEs) occur only when the concave regions are homogeneous, which led to the proposal that CCEs develop when the interpretation of a single background surface can be fit to concave regions, a fit that becomes increasingly likely with increased numbers of homogeneous concave regions. CCEs take time to develop: For 100-ms masked displays, CCEs are observed with a display- mask ISI of 100 ms, but not with 0- or 50-ms ISIs (Salvagio & Peterson, VSS, 2010). Here, we investigate why it takes time for CCEs to develop. With black-and-white displays used previously, both convex and concave regions were homogeneous, so perhaps a bias to see homogeneous regions as a single surface competed with a bias to see convex regions as figures and the mask cut short the time required to resolve this competition. To remove this potential source of competition we used displays with heterogeneous convex regions and homogeneous concave regions. At both 0- and 50-ms display-mask ISIs, we observed significantly larger CCEs with these displays than with black-and-white displays, ps <.03. Moreover, larger CCEs were observed with a 50- than a 0-ms display-mask ISI, p <.01, indicating that the possibility of perceiving the concave regions as objects also competes with the bias to see homogeneous regions as a single surface, and this competition takes time. Our investigation of the temporal dynamics of CCEs uncovered two previously undocumented competitive interactions in figure-ground perception.

Acknowledgement: MAP - NSF-BCS-0960529

43.513 **Texture-modulation channels for spatial frequency and orientation**

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Second-order orientation-modulated stimuli are thought to be processed by a two stages mechanism : the first, processing the carrier in striate cortex and the second, processing the modulation in extra-striate cortex. Much is known about the spatial properties of the mechanisms underlying carrier detection however little is known about the properties of the mechanisms involved in modulation detection and integration of carrier-based information. Here we propose to investigate the properties of spatial channels underlying this detection of second-order texture-modulations. For this purpose, we chose to use a discrimination at detection paradigm, implemented by a two-by-two alternative forced choice (2x2AFC) protocol. This protocol allows a normalized indicator of the performance, thus comparable across sessions and subjects and a perfect discrimination test. We show that the mechanisms underlying modulation detection are tuned for relative modulator spatial frequency and orientation, namely channels of about 1-2 octaves for spatial frequency and 30° for orientation. This tuning is not substantially different from that previously described for carrier mechanisms. Furthermore, for orientation, these stimuli exhibit an oblique effect which could be modulated by carrier orientation, suggesting facilitative interactions between first and second stage processes. To conclude, these observations suggest sub-mechanisms tuned for modulation orientation that are similar in their tuning to that previously reported for 1st order, luminance-defined stimuli. They also support a model of two mixed processing stages, one for carrier and one for modulator and highlights the need to better understand the types of interactions that occur between 1st and 2nd order processes, probably at different stages in ventral and dorsal pathways. In a near future, we will investigate these physiological aspect by modulating cortical excitability with repetitive transcranial magnetic stimulation (rTMS).

Acknowledgement: NSERC (46528-11)

43.514 **Reduced crowding and poor contour detection in schizophrenia are consistent with weak surround inhibition**

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People with schizophrenia (SZ) exhibit deficits in visual processing, including markedly poor detection of extended contours. Although this has been attributed to a deficit in binding or global integration – i.e. an inability to pool local structure across space – here we present evidence that it likely originates from a combination of poorer local processing (in this case, of orientation) combined with abnormal processing of visual context. We first report that although patients are poorer at detecting contours embedded in random noise they are proportionally less disrupted by the presence of near-parallel surrounds than healthy controls (consistent with earlier reports of reduced surround suppression in SZ). Second we show that patients’ ability to report the orientation of the local components of these contour patterns is (a) poor and (b) also less affected by the disruptive influence of distractor elements (visual crowding). We suggest that reduced sensitivity to local orientation, and to orientation-context, could result from abnormal gain control which is implicated both in the generation of orientation-tuning in visual cortex and in surround suppression.

43.515 **Continuous Transilience Induced Blindness — H-V Anisotropy and Luminance Asymmetry of disappearance —**

Ryo Shohara[1](1BDRM018@mail.tokai-u.jp), Makoto Katsumura[1], Seiichiro Naito[1]; [1]Human and Information Science, Tokai University, Hiratsuka, JAPAN

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Introduction: The transilient inducer changes lead to the transient disappearance of large figures (VSS2011-26:413). We devised the improved inducer which repeated the continuous transilience (CTIB) so that the disappearance was perfectly synchronous to the inducer and could last 1 second. We investigated the horizontal-vertical anisotropy and the luminance asymmetry. Methods: On the black (0.341cd) background, two white (110cd) filled circle with 10 degree diameter stationary targets were presented at lateral 10 degree eccentricity. The inducer was the six concentric circles which appeared one by one at the edge of the target and expanded over 5.25 degree. They were separated at 0.525 degree each other. The first circle was gray (5.15cd), and the consecutive circle colors were changed to black in linear manner. All of them expanded over the annulus then disappeared. The inducing sequence completed in 1800ms. After the inducer was OFF the target remained ON up to 4500ms. The whole sequence repeated indefinitely. The orientation of the targets was set either at horizontal, +45 degree, vertical, and -45 degree angle. For luminance asymmetry condition, on the white background the black targets were presented. The inducer was light grey (42.4cd). The vertical orientation arrangement was examined. Results: We found the marked anisotropy that the horizontal condition was difficult to disappear which yielded less than 5% of time cumulative disappearance. The vertical condition gave more than 50% time cumulative disappearance. We had the graded disappearance ratio for oblique orientations. The clear luminance asymmetry was also discovered. The black on white condition yielded 10% of cumulative disappearance ratio contrasting to the 50% of white on black condition. Conclusions: The results gave more confident evidence for H-V anisotropy, though it would be controversial to the conventional MIB results. The On-Off cell asymmetry would not likely be the origin of the luminance asymmetry.

43.516 Test-Retest Reliability of a Contour Integration Test in Samples of Healthy Control and Schizophrenia Subjects

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Introduction: Contour integration tests have clarified mechanisms of perceptual organization in humans and monkeys, in children and the elderly, and in disorders such as amblyopia and schizophrenia. However, the test-retest reliability of the contour integration paradigm is unexplored. Establishing this aspect of the paradigm is useful for assessing the effects of aging, pathology, or response to treatment. Methods: Participants with schizophrenia and healthy age-matched controls completed 3 contour integration assessments, 7 and then 14 days apart. On each trial, subjects judged whether a subset of otherwise randomly oriented Gabor elements formed a leftward or rightward pointing shape. Task difficulty depended on the amount of orientation jitter added to the target elements: 0°, 7°, 9°, 11°, 13°, 15°. The number of controls and patients for the three sessions were: 1) 122, 93; 2) 120, 93; 3) 118, 93. Test-retest reliability was calculated for accuracy and fitted-Weibull threshold estimates, using both intraclass correlation (ICC) and Spearman rho methods. Results: ICC estimates for accuracy varied with jitter condition. For conditions in which controls could reliably perceive contours, the ICC values for accuracy scores ranged from .62-.80 across Times 1-2, and from .56-.86 across Times 2-3. For schizophrenia patients, value ranges were .59-.86 and .71-.87, respectively. ICC values of threshold estimates were .56 and .46 for controls, and .28 and .64 for patients. Spearman rho values for threshold estimates for controls were .46 and .50 for Times 1-2 and 2-3, and .47 and .49 for patients. Additional analyses examined reliability across Times 1-3, and differences when subjects with poor acuity were excluded. Conclusion: This version of the contour integration test has fair-very good test-retest reliability. Reliability varied as a function of subject group (patient vs. control), calculation method (ICC vs. correlation), and unit of analysis (accuracy level vs. threshold estimate).

Acknowledgement: National Institute of Mental Health

43.517 Continuous Transilience Induced Blindness — Annulus, Sectors, and near fovea elements disappearance —

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Introduction: The transilient inducer changes lead to the transient disappearance of large target figures such as a 14 degree diameter filled circle (VSS2011-26:413). We devised the improved inducer which repeated the continuous transilience so that the disappearance lasted while the inducer was changing (CTIB). We investigated the disappearance of the large annulus and the triangle sectors which extended from close to the fixation point to the far periphery. They were the most difficult targets to disappear. The targets were uniformly filled or filled with lines which were either parallel or perpendicular to the inducer edge. The other curious issue was how much extent close to the fovea could be possible the CTIB. Methods: On the black (0.341cd) background, the white (110cd) stationary annulus target with 12.25 and 8.75 degree of outer and inner radius was presented. The inducer was the inner and outer six concentric circles which appeared one by one at the edge of the target and expanded or shrank over 7 degree. They were separated at 0.875 degree each other. The first circle was gray (5.15cd), and the consecutive circle colors were changed to black in linear manner. All of them reached at 7 degree in or out then disappeared. The inducing sequence completed in 790ms. After the inducer was OFF the target remained ON up to 2000ms. The whole sequence repeated indefinitely. For the triangle sector target, the methods were similar except the geometry. Results: For either annulus or sectors, we found that the filled targets were difficult to disappear. The targets filled with lines, however, were fairly easy to disappear. The typical optimum disappearance ratio was more than 50%. The targets at very near to the fixation point up to 0.5 degree also disappeared. Conclusions: We extended MIB. The results suggested novel conditions for disappearance.

43.518 Measuring the effects of belief on Kanizsa shape discrimination and illusory contour formation: A replication

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PURPOSE. Prior research has shown that belief about contour connectedness alters global shape integration but not illusory contour formation. Here, we aim to replicate those results while also independently verifying that subjects adopted the instructed belief. METHOD. Subjects discriminated briefly-presented, partly-visible fat and thin shapes, the edges of which either induced or did not induce illusory contours (relatable and nonrelatable condition, respectively). Half of trials of each condition incorporated task-irrelevant distractor lines, which disrupt contour filling-in. Half of the observers were asked to treat the visible parts of the target as belonging to a single thing (group strategy); the other half were asked to treat the parts as disconnected (ungroup strategy). A strategy was encouraged by giving subjects pictures of fat and thin response templates in the experiment instructions, and after every 20 trials. These pictures depicted either unitary shapes or fragmented shapes, depending on strategy. After each half of the experiment, subjects were asked how they cognitively regarded the stimulus. Task-naïve judges evaluated the responses. RESULTS. The results confirmed previous findings. Distractor lines impaired performance more in the relatable condition than in the nonrelatable condition (p=.001). Strategy did not alter the effects of distractor lines in the relatable trials or the nonrelatable trials (ps>.25). The attempt to group relatable fragments improved performance (p=0.004), while the attempt to group nonrelatable fragments did not (p>.5). Finally, 90% of the subjects were evaluated as having adopted the instructed strategy on both halves of the experiment. CONCLUSIONS. These new results show once again that a) filling-in effects during illusory contour formation cannot be easily removed via top-down strategy; b) filling-in effects cannot be easily manufactured from stimuli that fail to elicit interpolation; c) actively grouping fragments can readily improve discrimination performance, but only when those fragments cause interpolation.

43.519 **Perceiving Statistical Significance**

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The use of statistics has proliferated over the years so that research is now interpreted on the basis of p-values, with significance threshold sociologically determined as a p-value of 0.05 or less. While researchers commonly use statistical software to test for significance, human perception of significance has yet to be studied. Identifying our intuitions of significance helps one understand rapid-fire human perceptual judgments of high volume data (signal) embedded in noise, and has the potential to uncover our subjective biases and therefore, be a launching board toward removing these statistical "blind spots". Above all, it is a window into the true threshold of statistical significance in the human brain. Here, we examine the ability of adult humans to visually discriminate between two normal probability distributions that have i) identical means but differing variance: the variance of the test distribution on a given trial being 1.21, 1.44 or 3.24, and ii) identical variance but differing means: the mean of the test distribution on a given trial being 0, 0.1, or 0.3. In both experiments, the standard distribution had zero mean and unit variance. On a given trial, 2000 points (equally chosen from the two distributions) were displayed in two different colors. The observer had to judge, in a binary choice paradigm, if the two colors were similarly or differently arranged. On each trial, we calculated the p-value of the null hypothesis using Kolmogorov-Smirnoff statistics. Observers ($N = 15$) were less likely than statistical tests to reject the null hypothesis, i.e. to judge the two distributions as different. Even on trials in which the two distributions were highly discriminable (p-value <0.0001), observers did not judge them as such on i) 48% and ii) 14% of trials, on average. Further analyses and experiments will test sensitivity to p-value.

43.520 **Are We Biased to Perceive Normality?**

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The normal distribution is a continuous probability distribution with a bell-shaped probability density function that is widely used in modeling noise; it also emerges from the central limit theorem, which states that the sum of a large number of random variables in the limit approaches normality. Given the ubiquity of the normal distribution in signals around us, we wondered if humans have developed (or have evolved) a bias to perceive it. In other words, are we hard-wired to perceive a normal distribution under noisy visual conditions? As a first step to address this issue, we designed an experiment to measure perceptual bias for the normal distribution over the uniform one in a visual psychophysical design. The two distributions had identical mean and variance and were displayed on two separate figures side by side on a computer screen (5000 points each). A two-dimensional hybrid test stimulus was designed that comprised data points from both distributions in roughly equal proportions for a total of 5000 points. The hybrid stimulus was designed so that the median log odds ratio of the normal to uniform distributions was near zero across (100/observer) trials. The same hybrid test stimulus points were displayed in the color red on both figures, while points from the two pure uniform and normally distributed stimuli were displayed in blue; the naïve observer (N=15) had to choose the pure distribution that more closely resembled the arrangement of the red, hybrid one. Across trials, observers were significantly biased to favor the uniform distribution over the normal one ($p = 0.016$; 9 showed a significant bias toward uniform, 1 towards normal). Additional experiments with variable number of data points and higher range of log odds ratio further confirm these findings. The human visual system is not biased toward perceiving normality.

43.521 **Do We See a Least Squares World Around Us?**

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For years, researchers have fit experimental data using the method of least squares, which minimizes the sum of squared residuals (observed – fitted). There are clear numerical and analytical benefits to this method of data fitting, including the fact that least squares is the maximum likelihood error estimate if the errors follow a gaussian distribution. However, does the computed best fit align with our perceived best fit, and do we perceive the least squares fit to be the best fit? Observers (N=17) viewed a set of points on an x-y plane that were jittered about a straight line, with each point's noise amplitude drawn from a uniform probability distribution (future experiments will draw from a gaussian distribution). The x-y data were fit with straight lines that yielded either the optimal least squares error, absolute error, or fourth order error. Observers were then asked to choose the line that they perceived as being the best linear fit of the points given. No restrictions on time were placed on response. Observers were significantly less likely to choose the optimal least squares line fit (~25% trials): Statistical tests showed a modest but significant preference across observers for the absolute (39+/-0.5%) and fourth power (34+/- 0.3%) regression fits over the least squares (27+/-0.3%) fit ($p<0.05$ each). Observers significantly preferred the absolute fit over the fourth order fit if the number of data points was either very low (5 points) or very high (100 points). Preferring the line that optimizes the absolute error argues that we do not weight larger error residuals (non-linearly) more (fourth order fit), or that we trade off between penalizing poor data fits and assigning equal weight (least squares would have been a suitable compromise). Regardless, it is clear that humans do not perceive the least squares fit as optimal.

3D perception: Space

Monday, May 14, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

43.524 **Perception of depth in pictures when viewed from the wrong distance**

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Pictures can create very realistic impressions of 3D scenes. However, only one viewing position—the center of projection—yields the correct retinal image for the depicted 3D scene. Viewing from the wrong angle yields depth-related shearing in the image, and viewing from the wrong distance yields depth-related compression or expansion. People can compensate well for viewing from the wrong angle. It is unclear whether people can compensate for incorrect distance: Some studies found evidence for compensation, and others did not. The stimuli in these studies differed greatly. They ranged from line drawings to photographs, with and without familiar objects. Some provided low-level cues that could have allowed subjects to perform the task correctly even though they did not exhibit compensation. To determine whether compensation for incorrect distance occurs, we conducted a psychophysical experiment in which we manipulated realism and object familiarity. We also designed the experiment so that low-level cues would not allow correct performance. The stimuli consisted of pictures of two rectangular planes joined at a hinge. The planes were textured with a regular grid. We varied the hinge angle to determine the value that appeared to be 90°. The stimuli were line drawings or realistically textured computer-generated images with and without familiar shapes. Although the angle perceived as 90° differed greatly for line drawings and realistic renderings, we found no evidence that observers could compensate for viewing from the wrong distance, even with realistic renderings containing familiar objects. If they cannot compensate for incorrect distance, why do people generally not notice distortions with everyday picture viewing? We show that people naturally tend to view pictures from nearly the correct distance in part because of the lenses used by photographers.

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43.525 **Euclidean geometry of binocular space under natural viewing conditions**

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A number of studies reported that the visual space is systematically distorted, although the nature and magnitude of the distortions varied across studies. One of the well known tests was performed by Foley (1972) in his triangle experiment. He asked a binocular subject to adjust the positions of two lights, A and B, placed at the eye level, so that the triangle formed by these two points and the subject herself (represented as point O) was an isosceles right triangle (OB=AB, angle OBA=90 deg). The actual ratio AB/OB of a perceptually isosceles triangle was 0.53. At the same time, the angle AOB was perceived accurately as being 30 deg (instead of 45 deg), which implied that the visual space is a non-Euclidean space with negative curvature. It is important to point out that the viewing conditions in Foley's experiment were very impoverished. Since 3D vision is a difficult inverse problem whose solution critically depends on the operation of a priori constraints, perception cannot be veridical unless natural viewing conditions are used so that all natural constraints are effective. We identified several constraints which allowed our model to recover 3D space veridically (gravity, horizontal floor, subject's height). The present study replicated Foley's experiment in a variety of conditions from very impoverished to natural. Three independent variables were manipulated: lighting of the room (dark vs. bright), the level at which the targets were placed (eye level vs. floor), and the number of targets (2, like in Foley's experiment vs. 3). The subject's head was free to move. For 3 targets in a bright room, the perception was close to veridical (the visual space is Euclidean). With a dark room, or with 2 targets, perception was not veridical and the distortion of the visual space was similar to that reported by Foley.

Acknowledgement: AFOSR, DoD

43.526 **Shadow-Induced Jumping in Depth**

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An object's shadow can profoundly influence the perceived position and movement of the object in a scene (Kersten et al., 1997 Perception, 26: 171-192). When an object's shadow makes a discrete jump from one location to another, the object can appear to jump in depth despite not having moved in the image (Kersten et al., 1997 Nature, 379: 31). Here we use a variant on these displays in which an object in a perspective scene is immobile while its shadow is successively in different locations. If the shadow is initially attached to the object and then detached beneath it, one perceives the object to have jumped forward in depth. In a variant of this display, the shadow is initially attached to the object and then disappears. The object appears to move forward in the scene and float above the ground just as if its detached shadow were present. Multiple interpretations of the shadow's disappearance are possible including the sun being occluded by a cloud, the light source making an extreme jump in position and so forth. The perceived change in position may be due to the observer preferring the assumption of central tendency rather than the extreme position (at the end of the line of sight attached to the floor), or that the shadow has moved out of the viewport on the display. We find that one can perceive several objects jumping in depth if their shadows jump in the same direction in the scene. However, if the shadows undergo different directions of motion (e.g. consistent with some objects moving toward and others away from the viewer), one can perceive only a few (two or at most three) object jumps in depth, suggesting that the association of objects with unattached shadows is very taxing for the visual system.

43.527 **Signal detection theory cannot distinguish perceptual and response-based biases: Evidence from the Muller-Lyer illusion and application for action-specific effects**

Jessica Witt[1](jkwitt@purdue.edu), Eric Taylor[1], Mila Sugovic[1], John Wixted[2]; [1]Purdue University, [2]UC-San Diego

According to the action-specific account of perception, perception is influenced by the perceiver's ability to act. For example, softball players who are hitting better than others see the ball as bigger. These claims have been challenged on the grounds that the apparent effects in perception may be due to influences on the post-perceptual processes that generate the responses. Signal detection theory (SDT) seems poised to resolve this issue because it produces separate measures that are often linked to perceptual and decision-based processes. However, we will illustrate that SDT cannot distinguish perceptual biases from decision-based biases, and thus cannot be used to determine if action-specific effects are perceptual. Our illustration involves both an empirical demonstration and a graphical presentation of how a more advanced understanding of SDT would lead to the same conclusion. For the empirical demonstration, we used the Muller-Lyer illusion because it is analogous to the purported effects reported by the action-specific approach in that it leads to a perceptual bias. We found that the Muller-Lyer illusion did not influence d' and rather influenced the criterion measure (c). In many contexts, this pattern of results would lead to the conclusion that the illusion is not perceptual. Instead, we claim that the illusion is perceptual but that SDT cannot distinguish between perceptual and response-based biases. We then dissect the measures of SDT and illustrate how the measure of c would reveal an influence of both a criterion shift (as in the case of a decision-based process) and a perceptual shift (as in the case of a perceptual bias). Therefore, even though action-specific effects influence c and not d' (as shown in Experiment 2), this pattern of results cannot be interpreted as evidence that action-specific effects are not perceptual.

Acknowledgement: NSF BCS-0957051

43.528 **The dependence of the perception of distance on the height of the observer's vantage point**

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The distance from the observer to an object on the ground plane (egocentric distance) can be recovered from the information about the height of observer's vantage point and the information about the angular declination of the object (angle subtended by the direction to the horizon and the direction to the object location on the ground plane). Egocentric distances are generally underestimated. It has been suggested that this is due to overestimation of angular declination by a constant factor. With distance held constant, this hypothesis predicts that underestimation will be more pronounced for greater heights of the vantage point. We tested this prediction in two experiments. In Experiment 1 observers judged distances in three conditions: lying on the ground, standing, and standing on a 80 cm high platform. The object whose distance was judged was an experimenter (E1), standing on the ground at 5, 10 and 15 meters from the observer. Observers judged E1's distance by instructing a second experimenter (E2) to move away or towards E1 in order to make the E1-E2 distance the same as the E1-observer distance. The E1-E2 direction was perpendicular to the E1-observer direction. We replicated the general underestimation of egocentric distances. However, we found no effect of vantage point height. In Experiment 2 observers were either standing on the ground or on a platform. Their task was to match the distance of a small object at their eye height to the distance of another small object lying on the ground, and vice versa. The positions of the objects were manipulated through a system of cords and pulleys, and their to-be-matched distances were 1, 3 and 5 meters. An ANOVA followed by Scheffe tests found no effects of height of vantage point in any condition. Thus we were not able to confirm the angular declination hypothesis.

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43.529 **Perceptual Dependence of Size and Distance? A Within Subjects Variability Approach**

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Are percepts of size and distance coupled or independent? According to the size-distance invariance hypothesis and Emmert's Law (Emmert, 1881; Gilinsky, 1951), perceived size is derived from apparent distance and the visual angle of the object. In contrast, Gibson (1979) posited that size and distance are perceived independently. Many studies have supported a relationship between estimates of size and distance, typically through positive correlations in mean values. However, to truly assess perceptual independence, mean values alone are insufficient as common visual information can produce a positive mean correlation (sampling dependence). Using principles of General Recognition Theory (GRT, Ashby & Townsend, 1986), means and variability of action measures of size and distance were compared to determine if the percepts converged on the same underlying construct, or were disassociated. In Experiment 1, participants viewed three spherical objects (one at a time) located on the ground plane. Participants performed two counterbalanced blocks of trials: a size judgment block (indicate object size using hands), and a distance judgment block (walk without vision to a previously viewed target location). A measure of intra-individual standard deviation was calculated for each participant for each block type. A repeated-measures correlation coefficient (rm) was calculated through the methods of Bland (1995), yielding a weak correlation between size and dis-

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tance percepts, rm=.15, N=20. To alleviate the potential concern that participants used a memory strategy due to the small number of targets, in Experiment 2 we used 9 targets of 4 different colors, again yielding a weak correlation, rm= .08, N=12. Together, these results argue for the perceptual independence of size and distance percepts. Findings from a related experiment suggest that size and distance percepts might be less independent in conditions of degraded vision. We are currently conducting a follow-up study which compares size and distance judgments in degraded viewing conditions.

43.530 The Role of Visual Foot Size in Perceiving Object Size from Texture Gradient

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The ground plane's texture gradient is a well-known, perspective depth cue that derives from the fact that, for a uniformly textured surface, texture elements become smaller and more densely arrayed in the visual field with increased in distance e.g. grass on a field or cobble stones on a street. This size / distance relationship also occurs for objects such that objects of equal size occlude an equal amount of texture at their base regardless of their distance from the observer. Texture gradients have been studied primarily as a relative depth cue that specifies the size of one object relative to another. However, more definite relative scaling can be achieved if the size of texture elements is scaled to some known metric. We hypothesized that perceivers use the amount of texture occluded by their own feet to scale the sizes of objects on a textured ground. Using head-mounted displays and a motion capture system, we were able to increase or decrease the apparent size of participants' visual feet in a virtual environment. We asked participants to verbally estimate the width and height of many objects using meters and centimeters(varying in size at the base). As hypothesized, perceivers' estimations of the sizes of cylinders were smaller when participants had larger virtual feet and larger when participants had smaller virtual feet. This demonstrates that texture gradient, in combination with the visual self-located body, can be used to estimate the size of objects.

Acknowledgement: Alexander von Humboldt Foundation

43.531 Do athletes see space differently?

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Many varsity athletes participate in sports for which there are standardized dimensions with which they are familiar. In baseball, the distance to first base is 90 feet (27 m). In basketball, the rim of the basket is 10 feet above the court. We compared varsity athletes with other students using distance and height estimation tasks, perceptual matching tasks and action tasks (walking and throwing). Unsurprisingly, all participants were fairly well calibrated for throwing and for walking to targets 7.5 m away. Athletes were less variable, as a group, in their walking performance than non-athletes, $F(22, 25) = 2.42$, $p = .0173$, (COVs of 7% and 16%), but both groups were similar in throwing performance (COVs of 9% and 11%). Variability seemed to be in performance, not perception: There was no correlation between walking and throwing performance in either group, nor was either action measure correlated with verbal estimates. Our varsity athletes were more likely to be familiar with common sport dimensions (even for sports they did not play), and were much more accurate at estimating our far distances (e.g., averaging 12.1 m estimates for a distance of 12.5 m) than were other students (9.9 m), $t(47) = 2.09$, $p = .045$. Estimates of height, however, were similarly accurate for the two groups; most people reported using units of human height for comparison. Crucially, when engaged in a perceptual matching task -- matching their egocentric distance from a pole to the vertical extent of the pole -- athletes performed nearly identically to non-athletes (e.g., both groups judged an egocentric distance of 31 m to be equal to the height of a 20 m pole). It appears that the perceptual experiences of distance for the two groups did not differ, but that the varsity athletes were much better calibrated at verbally estimating longer distances.

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43.532 The effects of aging on egocentric distance judgments in 3-D scenes

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Previously we reported that older adults were more accurate in judging egocentric distance than younger adults (Bian & Andersen, VSS 2009). In the current study we examined whether this effect was due to differences in using eye height or texture gradient information between two age groups. In Experiment 1, twelve older (mean age = 68.4) and twelve younger observers (mean age = 21.3) viewed an outdoor scene (a large lawn field) binocularly and judged the egocentric distance of a target positioned at varying distances (4, 6, 8, 19, or 12m). The eye height (sitting, standing, or standing 0.85m above the ground) was also manipulated with the order counterbalanced across observers. On each trial an observer looked at the target in the scene and verbally reported its physical distance. We found older observers judged more depth than younger observers. However, the judged distances for both groups did not vary as a function of eye height. In Experiment 2, twelve older (mean age = 66.8) and twelve younger observers (mean age = 21.2) viewed an indoor scene (a hallway) monocularly through a rectangle viewer (16.9° × 52.1°) and judged the physical distance of a target positioned at varying distances (4, 5, 6, 7, 8, 9, 10, 11, or 12m). The texture pattern on the ground surface was manipulated by using a canvas (3.7 m × 12.2m) with no texture, a regular texture (random polka dots) or a random stripe texture pattern. The order of texture pattern was counterbalanced across observers. Again we found older observers reported more depth than younger observers. Neither age group varied their judged distances as a function of texture pattern. These results indicate greater precision among older individuals in using information for egocentric distance. The reliance on pictorial cues in distance perception with increased age will be discussed.

Acknowledgement: Supported by NIH AG13419-06 and EY18334-01

43.533 Estimates of visual slant are affected by beliefs about sugar intake

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Does blood glucose level affect slant perception? Manipulations of blood glucose typically involve requiring participants to fast before arriving in the lab and then having them drink an unidentified drink which either contains sugar or does not. Participant beliefs regarding the drink are rarely analyzed. In prior investigations we have found that participants tend to be biased to assume that they are being given a sugar drink. Effects attributed to low blood sugar might therefore actually be due to the combination of low blood sugar with the expectation of receiving sugar. To test the role of belief we gave all of our participants diet ginger ale, but half saw it poured from a bottle with the non-diet label. To keep the experimenter blind to condition, participants were assigned randomly to soda condition by a coin flip in the presence of one experimenter who then sent the participant by elevator to complete the study with a second experimenter who did not know what condition the participant was in. After a fatiguing cognitive task mimicking the tasks often used in glucose studies, participants were taken to a steep hidden stairway and asked to judge the angle of the stairs' ascent. A written instruction encouraged them to respond based only on what they saw. Participants who had received diet soda under the impression that it was actually regular soda gave much higher slant estimates (~50°) than those who correctly believed they had received diet soda (~40°), $p < .001$. A subsequent fatigue questionnaire found no differences between the two groups. Whatever the mechanism (misattribution or physiological changes induced by the expectation of sugar), these results suggest that hidden glucose manipulations are likely contaminated by expectancy or misattribution effects.

Acknowledgement: R15EY021026-01

43.534 Judgment of angular declination, but not of vertical angular size, is accurate

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Phenomenological visual space provides a basis for perceptual judgments of spatial relationships. The latter, in turn, allows us to reveal the intricacies of space perception. However, not all spatial judgments are reliable. One reason could be due to an inadequate gauging rather than to inaccurate sensory information. We compared the judgments of angular declination (direction) and angular size over a range of 8o-35o in a full cue environment. In Experiment 1, observers instructed the experimenter to adjust the height (angular declination) of a sphere (0.84o) placed at 1.5 m to match that of a test target (0.69o sphere) at 0.5 m. We found a linear matching

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function of angular declination specified by, y=0.9746x-2.0324, where y and x are, respectively, the matched and test angular declination (R2=0.997). Remarkably, the finding of a slope approaching unity is similar to the previous finding by Ooi et al (2001) who used a blind walking-gesturing task in the dark. They showed that while an observer's walked distance and gestured height of a previously viewed dimly-lit target were inaccurate, the estimated angular declination was veridical. Experiment 2 measured angular size. Two vertically aligned test spheres (0.65o) were placed at 0.5 m. We found the matching functions are non-veridical and significantly affected by the distance and configuration of the matching targets. (i) The matching function of angular size is y=0.714x+4.784 (R2=0.998) when the two matching targets (0.84o spheres) were vertically aligned and placed at 1.5 m. (ii) The matching function is y=0.770x+1.037 (R2=1.000) when the two matching targets were vertically misaligned, wherein one was placed at 1.5 m (0.84o sphere) and the other at 5.63 m (0.39o sphere at the eye level). Altogether, our findings reveal that the visual system accurately gauges angular declination but not angular size.

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43.535 **Perception of inclination as a function of eye and head inclination**

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The experiment was designed to investigate the influence of the vertical orientation of the eyes and of the head on judgments of the inclination of visual stimuli about a horizontal axis. One stimulus was a 50 cm-long vertical luminous line. Detection of the inclination of such a line requires registration of binocular disparity, inclination of the eyes in the head, and inclination of the head to gravity. The second stimulus was a textured large surface. This stimulus provides extra information in the form of perspective and the overall pattern of disparity. A fixation point was placed at the centre of each stimulus at a distance of 50 cm and both stimuli were viewed in black surroundings. By turning a knob the observer rotated the initially vertical stimulus about a frontal horizontal axis passing through the fixation point until the stimulus appeared vertical with respect to gravity. Measurements were made with the line and textured surface in four conditions. (1) Head vertical, stimulus at eye level. (2) Head vertical, stimulus moved down 30˚. (3) Head tilted back 30˚ around the interocular axis, stimulus at eye level. (4) Head tilted forward 30˚, stimulus moved down 30˚. When the line was at an angle to the visual axis, as in conditions 2 and 4, it was perceived as rotated towards the gaze normal by several degrees. When the line was gaze normal but viewed with inclined head, the settings indicated that head inclination and/or eye elevation was underestimated, more so by some subjects than by others. Both these effects were greatly reduced when the subjects viewed the textured stimulus. When the eyes are elevated or depressed in the head the eyes manifest incylovergence and excylovergence, respectively. If cyclovergence, and it attendant cyclodisparity, had any effect it was overridden by the factors mentioned above.

43.536 **The Perception of Distance on a Slope**

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Ooi, Wu, and He (2001) demonstrated that observers rely on angular declination below the horizon (ADBH) to determine distance on horizontal terrain. The ADBH hypothesis states that an object's distance can be determined by d = h/tan(α), where d is the distance to the object, h is the observer's eye height, and α is the ADBH corresponding to the object (Figure 1). Thus, objects close to the horizon appear further away and those further from the horizon appear closer to the observer. Would the ADBH hypothesis apply to targets placed on sloped surfaces? We hypothesized that objects on a sloped surface should be perceived as further away than objects placed at the same distance on a horizontal surface. Participants estimated the distance to a cone on a ramp laid flat or elevated at either 5 or 10 degrees (Figure 2). Participants viewed the cone, placed a blindfold over their eyes, turned 180 degrees, and walked a distance they believed replicated the distance previously viewed. Distance estimates became exaggerated as surface inclination and target distance increased (Figure 3). Blind walking may have introduced a perceptual distortion, but another alternative might be that we simply did not present the data using specifying variables. We recast the actual and perceived object location as an ADBH, scaled to eyeheight. Perceived ADBH mapped 1-to-1 onto actual ADBH irrespective of surface slope (Figure 4), consistent with the hypothesis that ADBH is invariant, body-scaled information for distance perception. Is reliance on ADBH based only on perception, cognition, or both? Participants both observed and responded to targets on a 10 degree slope significantly longer than on other surfaces (Figure 5). Any extra time devoted to observation and responding did not influence the quality and nature of reliance on specifying information, thus obviating the need for cognitive interpretations.

43.537 **Size judgments for nearby and distant objects: A test of the perceptual learning and metacognitive theories of size constancy development**

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This study investigated size estimation accuracy for nearby and distant objects. Five age groups were tested: 5-6 years (n= 19), 7-8 years (n= 11), 9-10 years (n= 12), 19-28 years (n= 20), and 50+ years (n= 18). Previous studies found that before 9 years children underestimate the sizes of distant objects, whereas older children and adults tend to overestimate their sizes. According to the perceptual learning theory, young children's underestimations result from lower sensitivity to monocular depth cues. According to the metacognitive theory, children become increasingly aware of their underconstant perceptions of distant objects after 8 years of age and begin to strategically inflate their size estimates. Participants judged the size of a standard disc (53.3, 61.0, or 68.6 cm in diameter) by pointing at one of nine comparison discs (15.2 to 76.2 cm in diameter). The standard disc was positioned at either 6.1 m or 61 m. Testing was conducted under both monocular and binocular viewing conditions. Participants were asked to explain their size-match choices and were categorized as using or not using a size-inflation strategy. Size estimation accuracy varied across age groups ($p<.001$). At the far distance, object size was underestimated by 5- to 8-year-old children, but was increasingly overestimated from 9 years on. Overestimation was greatest in the young adults and was less pronounced in the older adults. All age groups underestimated size at the near distance. Compared to the 5- to 8-year-olds, underestimation was reduced in the participants 9 years of age and older. Contrary to predictions from the perceptual learning theory, viewing condition had no significant effects. Consistent with the metacognitive theory, strategy use resulted in larger size estimates for distant objects. The results indicate age-related improvements in size estimation accuracy. They support the metacognitive theory but conflict with the perceptual learning theory.

43.538 **An angular expansion hypothesis quantitatively accounts for several well-documented biases in space perception**

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In the past few years, evidence has accumulated which suggests that many well-known spatial distortions might be related to systematic biases in two perceived angular variables – the perceived direction of gaze (e.g. gaze declination from horizontal) and the perceived optical slant of surfaces (Durgin and Li, 2011; Durgin and Li, in press; Durgin, Li and Hajnal, 2010; Li and Durgin, 2009, 2010; Li, Phillips and Durgin, 2011). It has been shown that in the range between 0° and 50°, both the perceived declination of gaze and the perceived optical slant of surfaces are expanded with a linear gain of about 1.5; perceived optical slant also increases as a function of viewing distance. An angular expansion hypothesis has been proposed which assumes that (1) there are perceptual biases in these two angular variables and (2) that the relationships between these and other perceived spatial variables otherwise still adhere to a Euclidean geometry. Specifically, it has been shown that such an angular expansion hypothesis can quantitatively account for known exaggerations in perceived uphill and downhill geographical slants, as well as underestimation in perceived egocentric distance, and also the foreshortening of perceived egocentric distance relative to perceived vertical distance (height). In the present study, we provide evidence that the perceived azimuthal (left-right) gaze direction is also systematically biased. In contrast to the bias in vertical gaze direction (i.e. gaze declination), bias in perceived azimuthal gaze direction is relatively small. By including a quantitative estimate of the perceptual distortion in azimuthal gaze direction, the angular expansion hypothesis can provide partial accounts of a broader range of phenomena, including exocentric distance anisotropy (i.e. foreshortening in sagittal distance relative to frontal distance), the vertical-horizontal illusion, and even size constancy.

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43.539 **Differential Detection of Visual Targets Presented in Near and Far Space and its Dependence on the Chromatic Properties of the Targets**

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Converging evidence from animal neurophysiology and human clinical studies has suggested that visual information arising from near (peripersonal, within arm's reach) versus far (extrapersonal, beyond arm's reach) space may be mediated predominantly by different visual subsystems in the human brain. In our recent study (Li et al, Neuropsychologia, 2011), we tested healthy human observers using either simple detection/localization or identification tasks, in a range of single- and dual-task situations. Healthy human observers showed a behavioural difference in detecting briefly displayed and retinally equivalent visual stimuli in near versus far space. However, identification accuracy under similar conditions showed no such dissociation of near versus far processing. Such differences in sensitivity for detecting visual target presented in near versus far space suggest that distinct neural processes or mechanisms might contribute differentially for near versus far visual information. Because the magnocellular pathway is only sensitive to luminance contrast while the parvocellular pathway is sensitive to both chromatic and luminance contrast, in the present study, we examined the detection performance further by manipulating the luminance and chromatic properties of the target. Healthy human observers were asked to detect a spot briefly presented in a random location at the peripheral visual field in near (0.39m) and far (1.33m) viewing conditions, with matched luminance and visual angle for the visual display in the two conditions. Similar to our previous findings, we found that the visual accuracy was higher in near viewing than far viewing when detecting an achromatic target in either high or low contrast. However, the near/far difference was reversed when the visual target was an isoluminant green spot. These data suggest that retinal information from near versus far space may be preferentially processed by substantially different neural substrates, with active modulation of the relative contributions of involved magnocellular-dorsal and parvocellular-ventral visual pathways.

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43.540 **A comparison of size perception in real and virtual environments using judgments of action capability.**

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3D scenes are often presented as pictures on desktop monitors. Much of the work on size perception in pictures has used measures involving visual matching. How observers perceive pictorial displays with respect to body-based judgments about action capabilities has not been examined, and may be relevant for applications intended to display act-on-able objects or environments such as in architectural design. Affordance judgments have been used in real and immersive environments, often focused on larger scale actions such as judgments of passage. Here, we use judgments of the ability to grasp a cube to test size perception on a computer desktop display. In the real environment, participants viewed the cubes on a table. In the graphics display, participants viewed a rendering of the same cubes and table on a desktop display. In both conditions, cubes were placed 50 cm and 70 cm from the participant. The cubes were viewed binocularly from a viewpoint location that matched the rendering location. Results were analyzed as a ratio of judged over actual ability. Results revealed a main effect of viewing environment. Participants in the desktop display judged that they could pick up larger cubes than when in the real environment. There was also an interaction of viewing environment and location. The effect of distance was greater in the desktop condition than the real environment. The desktop results are consistent with the size-distance invariance hypothesis, modified by the presumption that distance perception in pictures is affected by both the pictorial cues for distance and the distance of the screen. The real world results show that in the absence of a screen, the judgments are conservative and are minimally affected by distance to the objects. Work is underway to confirm these results with a reaching through measure.

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43.541 **Frontal extents are compressed in virtual reality**

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Action measures reflect the calibrated relationship between perception and action (Powers, 1973). There is evidence that egocentric distances are underestimated in normal environments even though people walk them accurately. One basis for this claim is that when people are asked to match a frontal extent with an egocentric one, they set the egocentric interval much too large. Li, Phillips and Durgin, (2011) conducted such matching experiments in both (panoramic) virtual (VR) and real outdoor environments. Similar matching errors were found in both environments, as if egocentric distances appeared compressed relative to frontal ones. In the present study we compared action measures (visually-directed walking) for egocentric and frontal intervals in VR and in an outdoor environment. Walking estimates of frontal distances were relatively accurate in VR, but walking estimates of egocentric distances were short. Geuss et al. (2011) have interpreted such a pattern of data as indicating that egocentric distances, but not frontal extents, are compressed in VR. However, the ratios of walking in the two conditions exactly correspond to the matched ratios found in the matching task both in VR and in an outdoor environment. Moreover, we found that walking measures overestimate frontal extents in outdoor environments (see also Philbeck et al., 2004). It seems that frontal intervals and egocentric intervals are both compressed in VR. Frontal intervals may be matched relatively accurately in VR by walking measures because the compression of VR approximately offsets the errors that are normally observed in real environments. Walking actions are calibrated during normal use, but walking is normally used to cover egocentric distances, not frontal ones. Because frontal intervals appear larger than egocentric intervals, it should be expected that walking out frontal intervals will produce proportionally greater estimates than walking out egocentric intervals even in VR.

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43.542 **Perceptual space asymmetry above and below the eye level reveals ground superiority in the reduced cue environment**

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Large background surfaces serve as a reference frame for egocentric target localization in the intermediate distance range. The visual representation of these surfaces (creating our perceptual space) relies on the visual system's intrinsic bias and external depth information. The intrinsic bias below the eye level is an implicit slant surface, and is revealed by measuring perceived locations of dimly-lit targets in the dark (Ooi et al, 2001). To understand how the terrestrial environment shapes visual processing, we explored whether space perception below the eye level is more accurate than above the eye level. Experiment 1 obtained the intrinsic bias using a blind walking-gesturing task that measured the perceived location of a dimly-lit target (0.2 deg) at 5 distances (1.5-7 m) and 2 heights (above and below the eye level) in the dark. We found the mean results for both the above and below eye level conditions exhibit the familiar intrinsic bias. However, the perceived distance is moderately farther (less underestimation) in the below eye level condition, suggesting some ground advantage. Experiment 2 tested the possibility of a ground advantage with weak texture cues (two parallel rows of dimly-lit elements) in a reduced cue environment. We measured the perceived target location in the presence of the texture array that was pasted 1.25m above, or below, the eye level. We found that although perceived distances are underestimated in both ground and ceiling texture conditions, the underestimation is significantly smaller in the former. This ground advantage, which is stronger than in Experiment 1, is also found when observers verbally reported the egocentric target distance. Altogether, our findings demonstrate that background surfaces below the eye level (ground-like), are more efficiently represented. The enhanced perception likely reflects an adaptation to our terrestrial existence (Bian et al, 2005; Gibson, 1950; McCarley & He, 1999; Sedgwick, 1986).

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Attention: Features I

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Poster Session, Vista Ballroom

43.544 Effects of feature-based attention on voxel tuning curves for individual faces

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Although it is known that attention changes the profile of neural population responses to low-level features, the influence of attention on the representations of complex categories such as faces are less understood. Here, we recorded fMRI responses to individual members of a set of morphed faces, constructed voxel-based tuning curves along the face morph axis, and examined how these tuning curves were modulated by feature-based attention directed to one of the faces. Analyses were conducted in voxels in inferior temporal and occipital cortex that responded preferentially to faces compared to scenes. Voxel-based tuning curves (Serences et al., 2009) were generated by measuring the responses of individual voxels to each of six faces along a morph continuum (F1 to F6). Cross-validation using independent data sets revealed that the majority of tuning curves exhibited significant selectivity for individual faces. Furthermore, tuning curves showed distinct characteristics in different areas: posterior face areas (FFA, OFA, STS) had significant tuning for individual faces, while more anterior face areas in temporal cortex showed more categorical tuning for faces (F1-3 vs. F4-6). In the attention task, individuals were cued to attend to just one of a pair of superimposed faces (F1 and F6) and to detect morphs of the attended face to a new face that was orthogonal to the F1-F6 continuum. Attending to one of the faces selectively enhanced responses to the superimposed face pair in voxels previously defined as preferring the attended face. These findings show that fMRI can be used to classify individual face preferences in single voxels. Furthermore, they demonstrate that directing attention to individual faces selectively modulates responses in individual voxels that are selective for facial identity. In addition, we are employing coherency analysis to identify regions that interact with voxels that are tuned for individual faces.

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43.545 Switching between optimal feature-based attentional gain patterns according to task demands

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Several recent studies have demonstrated that feature-based attentional gain is deployed to the most informative sensory neurons during discrimination tasks (e.g. Navalpakkam & Itti, 2007; Scolari & Serences, 2009). When making a coarse discrimination (e.g., identifying a 90 degree target among 180 degree distractors), attention enhances the response of neurons tuned to the target (on-channel gain) because these neurons reliably signal the difference between stimulus alternatives. However, when making a fine discrimination (e.g., identifying a 90 degree target among 95 degree distractors), attention enhances the response of neurons tuned to flanking orientations (off-channel gain) because these neurons undergo a larger firing rate change between target and distractors. While these two task-dependent patterns have been observed in discrete studies, here we explore whether subjects can appropriately switch between strategies in response to changes in the degree of target-distractor similarity. We estimated the shape of the feature-based attentional gain function during both fine and coarse orientation discrimination tasks (all subjects completed both task types in separate sessions, N=26). Following the methods of Scolari & Serences (2009), subjects indicated the location of a target Gabor patch that was rotated ±5 degree (fine) or ±90 degree (coarse) from three uniform distractors. On 33% of trials, we probed the distribution of gain by measuring detection accuracy for a single Gabor offset from the expected discrimination target by 0°, ±5°, ±10°, ±20°, or ±90°. Overall, we observed more on-channel gain during the coarse discrimination and more off-channel gain during the fine discrimination task. Furthermore, the best subjects showed the greatest difference in gain at the target orientation between task types. This suggests that individuals who most effectively deploy gain in one discrimination task are also likely to be most effective at switching gain patterns in accordance with altered perceptual demands.

43.546 Running the figure to the ground: Camouflaging targets during visual search

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Using a variant of the visual search task, we investigated how figure-ground segmentation processes might lead to the camouflage of a target item when it is embedded in an array of distractor items. Each search item consisted of a black region and a white region, roughly equal in area, such that either the white or black region denoted a meaningful and familiar object (i.e., it had high denotivity), whereas the other region did not depict a known object (i.e. it had low denotivity). Participants were first shown each image in isolation and asked to identify which region denoted a meaningful object. During subsequent search trials, participants were presented with a 4x4 array of items and instructed to locate the specified target item as quickly as possible on each trial. Both eye movements and response data were collected during search. Participants made a speeded detection response with the space bar, followed by a localization response to a masked display using the mouse (to evaluate accuracy). Critically, congruency of the target and distractors was manipulated. On congruent trials, the highly denotive region in each of the images was the same color (e.g., all black). On incongruent trials, the highly denotive region in each of the distractor images was the same color (e.g., black), while the highly denotive region of the target was the opposite color (e.g., white). We found that incongruent trials produced a 'camouflage' effect, whereby participants were significantly slower to locate incongruent target items compared to their congruent counterparts. This result indicates that segmentation of individual items is modified by the dominant global segmentation, inducing participants on incongruent trials to misclassify the ground region of the target as the figure, thus leading to a delay in target recognition.

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43.547 Stress and Visual Attention

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Previous studies have obtained contradictory conclusions regarding the effect of stress on visual attention. Some have reported that stress narrows attentional focus (Callaway and Dembo, 1958); others have reported that stress causes a broadening of attention (Braunstein-Bercovitz, 2003). To help resolve this situation, this study assessed the effect of mild stress on visual search. In a first experiment, two different conditions were used: short line among long lines, and long line among short lines. Prior to each task participants performed either easy (low stress) or difficult (high stress) math tasks (and were told that a debriefing (low stress) or a videotaped interview (high stress) would follow the experiment. The Short Stress State Questionnaire (Helton, 2004) measured stress induction effectiveness. Results show no difference in accuracy for different stress levels, but significantly faster response times and lower search slopes for the high-stress condition. In a second experiment using the same method we compared the effect of stress on two different tasks: conjunction search and feature search (similar to experiment 1). For the feature search task results show no difference in accuracy for different stress levels but significantly lower search slopes for the high-stress condition; For the conjunction search task, accuracy, response times and search slopes do not differ accross stress levels. The findings support the hypothesis of a broadening effect of stress on visual attention.

43.548 Change detection without localization in a change blindness task is based on pre-attentive registration of new features

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Theories of visual perception hold that visual scenes are initially decomposed into separate feature dimensions (e.g. color and shape), each represented on a separate map. Representations on these maps are 'unbound', meaning that they code only feature presence but not location or to which object they belong. It is assumed that we have no conscious access to information represented on feature maps, and that conscious perception requires that features belonging to an object be 'bound' by spatial attention. In the present study, we investigated whether unbound representations on feature maps can support at least awareness that 'something' has changed even

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when binding and recognition of the changing object fail. We presented scenes with tricolored objects in a change blindness paradigm. Each scene was presented several times, and one of the objects was changed from one presentation to the next. Changes either involved colors that were already present elsewhere in the display or entirely new colors. We reasoned that only the second type of change would lead to a substantial change on the color feature map while the first type would not. Observers were first asked to detect whether any change had occurred at all and then to localize the changing object. Observers were generally better at detecting and localizing changes when the change involved a new feature. Importantly, observers sometimes correctly detected the presence of a change without being able to localize it, but only when the change involved a new feature. This finding implies that pre-attentive processing of a change on a map of unbound features can give rise to a particular kind of perception - that something has changed somewhere - even when feature binding and perception of the object's identity fails. This process may underlie the previously demonstrated experience of 'sensing of changes' in change blindness tasks.

43.549 **Spatially selective visual attention in the real world**

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Most experiments on attention use impoverished stimuli – disembodied letters, numbers or simple shapes displayed on a blank background - ignoring the possible influence a richly detailed scene might have on attentional processes. In our study photographs of objects were set within a contextually relevant background. Participants used covert attention to identify the target among distractors and responded to a subsequent probe presented randomly. Faster reaction times for probes at object locations (target & distractor) compared to background locations were found regardless of distance from the target. Participants were able to flexibly distribute their attention, facilitating multiple, non-contiguous locations where a target might appear while inhibiting all background locations equally.

43.550 **Attending to one green item while ignoring another: Costly, but with curious effects of stimulus arrangement**

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Splitting attention between targets of different colors is not costly by itself. As we found previously, however, monitoring a target of a particular color makes one more vulnerable to interference by distracters that share the target color. Participants monitored the changing spatial frequencies of two targets of either the same (e.g., red and red) or different colors (e.g., red and green). The changing stimuli disappeared without warning and participants reported the final spatial frequency of one of the targets. In the different-colors condition, a large cost occurs if a green distracter is superposed on the red target in the first location and a red distracter is superposed on the green target in the second location. This likely reflects a difficulty with attending to a color in one location while ignoring it in another. Here we focus on a subsidiary finding regarding perceptual lags. Participants reported spatial frequency values from the past rather than the correct final value, and such lags were greater in the different-colors condition. This "perceptual lag" cost was found when the two stimuli were horizontally arrayed but not, curiously, when they were vertically arrayed. Arrangement was confounded however with processing by separate brain hemispheres (opposite hemifields). In our new study, we unconfounded arrangement and presentation in separate hemifields with a diagonal condition- targets were not horizontally arrayed but were still presented to different hemifields. No significant different-colors lag cost was found in this diagonal arrangement (5 ms) or in the vertical arrangement (86 ms), but the cost (167 ms) was significant in the horizontal arrangement, as in previous experiments. Horizontal arrangement apparently has a special effect apart from the targets being processed by different hemispheres. To speculate, this may reflect sensitivity to bilateral symmetry and its violation when the target colors are different.

43.551 **Amodal completion of unconsciously processed objects**

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In the visual environment objects often appear behind occluding surfaces, yet they are automatically and effortlessly perceived as complete. Here we examined whether visual objects that are presented below the threshold of awareness are amodally completed when occluded. We used a priming paradigm in which participants responded to consciously perceived targets that masked preceding unconsciously presented primes. Discrimination responses to disk targets were faster when they were preceded by disk primes, regardless of whether the primes appeared complete or occluded by a horizontal bar. This priming effect was not produced by a partial match in features, since the occluded primes did not facilitate responses to another type of target (i.e., a pacman) with which they shared local features. These results show that unconscious visual objects can be amodally completed and corroborate the view that unconscious processing occurs at greater depths than previously considered.

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43.552 **Attentional Selection of Simple and Complex Objects**

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In addition to spatial locations, perceptual groups (i.e., objects) within a visual scene can guide shifts of attention (e.g., Egly et al., 1994; Vecera, 1994). One common method used to observe both space-based attention and object-based attention (OBA) effects is a spatial cuing paradigm where attention is summoned to one of two objects using a peripheral cue. Targets then appear at 1) the cue's location (valid), 2) an uncued location on the attended object (invalid same-object), or 3) an uncued location on the unattended object (invalid different-object). OBA is illustrated by faster responses to invalid same-object trials than invalid different-object trials. One explanation for this effect is that attention spreads through the object, enhancing its representation (see Richard et al., 2008, for discussion). If attentional spreading produces the OBA effect, is it impacted by the complexity of the object? The current experiments examined the influence of an object's structure on object-based shifts of visual attention. Observers viewed single-part objects and three-part objects in a spatial cuing paradigm. Critically, we varied the inter-stimulus interval (ISI) between the cue's offset and the target's onset (0, 100, 350 ms). OBA effects emerged at all ISIs for single-part objects. In comparison, an OBA effect was only observed at a 350 ms ISI for multipart objects. Because response times for invalid same-object trials decreased as ISI increased, these results suggest that attention requires time to spread through complex objects in order to observe the OBA effect in a spatial cueing paradigm. Furthermore, OBA is a mechanism that does not operate identically over all perceptual groups; rather, it is further influenced by the nature of a selected perceptual group.

Acknowledgement: NSF grant BCS 03-39171 awarded to Shaun P. Vecera

43.553 **Feature based attention and visual stability**

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Primate visual system has been shown to compensate for eye movement induced retinotopic shifts in the visual image. For instance, neurons with receptive fields coding for post-saccadic retinotopic stimulus location are activated even before a saccade starts. Similarly, spatial attention also predictively shifts to the post-saccadic stimulus location. Such predictive updating of spatial location information is considered to be the mechanism mediating visual stability. However, contributions of attended object features - such as shape or color - have been relatively neglected. We investigated feature based attention across saccades and its potential contributions to visual stability. In this study, we asked participants to do two things at the same time – to make a saccade to a colored dot and to discriminate a probe (a Gabor patch tilted to left or right) presented at a distractor location which either matched or did not match the color of the saccade target. Tilt discrimination performance hence served as a measure of feature based attention - before a saccade started, participants were better at discriminating probes presented at distractor locations that matched the color of the saccade target, than at distractor locations that did not match that color. This is a classic feature attention effect - allocating attention to one feature (color of the saccade target) lead to performance increases at other locations matching that feature (distractor locations matching that color). Importantly, we observed that immediately after the saccade was finished, feature based attention benefits persisted at the distractor location with matching color, regardless of the fact that it now had a different retinotopic position. Thus, feature based attention and predictive shifts of spatial attention could combine to quickly find the location of relevant objects across saccades.

43.554 **Phasic modulation of tonic attentional biases in horizontal and vertical dimensions: A cued visual line bisection study**

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Background. Biases of spatial attention occur in both horizontal and vertical dimensions. Normal observers exhibit a tonic leftward error in the perceived midpoint of horizontal lines thought to result from a surplus of spatial attention directed into the left (contralateral) hemifield (or toward the left half of objects) by the dominant right hemisphere which induces a left-side size overestimation. Less well-studied is the tonic upward error in the perceived midpoint of vertical lines which, interestingly, is common to both normal observers and neglect patients. Transient visual cues phasically modulate the tonic leftward error for horizontal lines; the effect of cues on vertical bisection error is unknown. Method. In two experiments (E1, E2) observers (N = 34 and 32) bisected horizontal (E1) and vertical (E2) lines (50% contrast; 26.7° by 3°; viewing distance = 57 cm), in both cued (3° diameter circular cosines, 3 c/d, 100% contrast, 30 ms duration, 60 ms cue-line SOA) and uncued conditons. In E1 horizontal lines cues appeared within the left and right line halves at eight spatial locations. In E2 vertical lines appeared within the upper and lower line halves at eight spatial locations. Results. In E1 a tonic leftward bisection error was significantly modulated by cues. Right cue potency exceeded left cue potency. Cues located inside line boundaries were equally potent, but those located outside were ineffective in modulating bisection error. In E2 a tonic upward bisection error was modulated by cues. Downward cue potency exceeded upward cue potency. Again, cues located outside the line boundary were ineffective; unlike E1, cue potency varied with location inside the line. Conclusions. Cues modulate tonic biases of spatial attention in both horizontal and vertical dimensions. Cue potency is strongest for cues which antagonize the tonic biases. Cues effects are exerted in object-referenced coordinates.

Acknowledgement: NIH COBRE P20 RR020151

43.555 **Integrating Bottom-up and Top-down Visual Attention for Object Segmentation**

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Visual attention is a ubiquitous mechanism found in sensory perception, especially in humans and other primates. While several computational models of attention are derived from the bottom-up sensory processing to extract saliency maps, shifts of attention are also thought to be generated from the top-down, through feature dependent weighting of the various feature dictionaries. In this abstract, we proposed an object segmentation framework by integrating bottom-up saliency maps with top-down attention, triggered by a sparse, hierarchical model of visual cortex called PANN (Petascale Artificial Neural Network). Similar to the previous HMAX/Neocognitron model, PANN is composed of coupled simple cell and complex cell layers. While simple cells build representations of features over successively larger receptive fields, complex cell layers associate the outputs of simple cells within the same layer to create representations of features that are increasingly viewpoint invariant. These representations are learned through a combination of unsupervised learning - which allows the system to acquire statistically features in its realm of experience - and supervised learning, which associates labels to specific clusters of features at the top layer. Through the hierarchical network, the spatial support of a classifier's decision can be traced down to input to create an informative map of which low-level image features were associated with the positive object foreground. As a result, this object relevance map becomes a useful measure of top-down attention. This object-based attention mechanism is applied to detect specific objects in an aerial video from a low-flying aircraft, and further to segment the whole objects within the same video by fusing bottom-up saliency maps. In that integrated manner, the bottom-up saliency maps can assist top-down attention to better segment the intact objects and top-down attention can assist saliency map to filter out unnecessary backgrounds.

Acknowledgement: DOE LDRD-DR program

43.556 **Online Discriminative Sparse Coding as a Systems-level Model of the Primate's Dorsal and Ventral Pathways**

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A widely accepted description of the primate visual cortex includes two information processing pathways: a ventral (or "what") pathway that computes properties of object identity such as shape and color, and a dorsal (or "where") pathway that computes properties of the location of stimuli on the retina. The current state-of-the-art work of visual cortex, including the well-known Neocognitron and HMAX models, exclusively concentrated on the modeling of ventral pathway to deliver the functionality for object identification. The fact that the two visual pathways are densely interconnected and interacted in the primate visual cortex was largely neglected. This work in contrast addresses how spatial ("where") and category ("what") representations could interconnect and interact via bidirectional processing and predict both location and identification of an object given a visual input.Our computational approach is based on the development of a scalable network model, which integrates a ventral pathway, dedicated to object identification, with a dorsal pathway, dedicated to object localization and segmentation. The network receive image stimuli and coupled "what" labels and "where" labels as three external signals, constructing a Y-shaped network as a hierarchy of (deep hidden) cortical layers. The sparse coding model at each level is l0-constrained and results in a highly efficient online learning that does not require iterative steps to reach a fixed point of sparse representation. The proposed sparse coding model can be further implemented in a divide-and-conquer manner to provide an effective solution to learn this deep network with bidirectional connections. A preliminary result has shown the network in small scale to deal with multiple objects slowing shifting in various natural backgrounds. The results have demonstrated the high accuracy of both attentional tuning and object recognition, as well as the interaction between them.

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43.557 **The capacity limit of feature-based attention: a cueing study**

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Attending to a feature (e.g., orientation, motion direction) enhances visual processing of that particular feature, indexed by both psychophysical and neurophysiological measures. However, it is not known how many features one can attend simultaneously. Given that one can attend to multiple spatial locations (e.g., Awh & Pashler, 2000; McMains & Somers, 2004), we might expect that one can also attend to multiple features. We tested this conjecture by measuring motion detection threshold with a cueing protocol. Each trial contained two intervals, with a random dot motion stimulus shown in each interval. One stimulus (noise) had 0% coherence (no net motion), while the other stimulus (signal) moved with varying levels of coherence in a particular direction. Subjects reported which interval contained the signal (two-interval forced choice) in one of three cueing conditions. In the 1-cue condition, a small line segment preceded the stimuli indicating the direction of the signal with 100% validity. In the 2-cue condition, two lines preceded the stimuli, indicating the signal would move in one of the two cued directions. In the no-cue condition, no line segment appeared before the dot stimuli. The three conditions were blocked and block order was counter-balanced. In several experiments, we consistently observed a lower detection threshold in the 1-cue condition than the no-cue condition, showing subjects can orient their attention to a single feature. However, detection threshold was consistently higher for 2-cue condition than 1-cue condition, indicating subjects could not prepare for two motion directions as effectively as one direction. This finding revealed a severe capacity limit in our ability to orient attention to multiple features.

43.558 **Constraining Attentional Selection by Two Orientation Cues: An Eye Tracking Study**

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We previously reported (VSS '11) that people could constrain attention to two distinct colors and that both colors biased attention in parallel. Here we investigated whether this ability generalizes to selection by orientation. Participants' eyes were tracked while they searched displays of 24 oriented

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bars for one with a small break on its left side. Each bar was set to be one of four equally spaced orientations (± 22.5° from vertical and horizontal). There were four cuing conditions (a single bar oriented +22.5° from horizontal, a single bar oriented -22.5° from vertical, both of these bars, or all four orientations). Participants were informed that the target, if present, would always appear in a bar of the cued orientation(s). Cuing conditions were blocked and block order was counter-balanced. Within cuing conditions there was also an effective set size manipulation such that the cued items were 6 or 12 of the items in the array. We analyzed reaction time, the number of fixations on each orientation, and the transitions between fixations. Results show that attention can be constrained based on an orientation cue, but it is not very effective. In addition, when the cue was +22.5° from horizontal, the distractors that were -22.5° from horizontal were fixated far more often than the distractors that were -22.5° from vertical (even though both types of distractors were 45° from the cue). A similar asymmetry appeared for the -22.5° from vertical cue. This asymmetry in distractor effectiveness suggests that the biasing of attention was based on a categorical description ("close to horizontal" or "close to vertical") rather than the precise cue orientation. Finally, we found no evidence that the two orientations could bias attention in parallel. These results are quite different from the color results and suggest that not all features are created equal.

43.559 **Perceptual size averaging: It's not just for circles anymore**

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Much recent research has explored the phenomenon of perceptual averaging: beyond constructing representations of individual objects, the visual system also computes statistical summaries of scenes (perhaps as a way of coping with capacity limitations). For example, observers are able to efficiently and accurately report the average size of an array of discs. To date, however, the displays used in such studies have been homogeneous in several ways that are not reflective of real-world scenes. For example, the arrays in such experiments have always used displays that contain identical shapes, varying only in size. To explore perceptual averaging for heterogeneous displays, observers viewed 1-second arrays of either pacmen or wedges (equated for area), where the angular extent of the wedges (or of the 'missing' wedges from pacmen) varied within each array. Observers reported the average area of such arrays using an adjustable test shape that matched the array shapes (e.g. using a constant-radius wedge whose angular sweep could be adjusted, or using a constant-angle wedge whose radius could be adjusted). Observers were no less accurate at averaging in this situation than when they reported the average area of an array of discs using a test disc. However, there was a marked cost of adding a different kind of heterogeneity at test: for example, when reporting average area using a test disc, observers are more accurate for arrays filled with discs than for arrays filled with either pacmen or wedges. Thus we see that perceptual averaging is relatively unaffected by some types of heterogeneity (e.g. within-array shape differences), but can be frustrated by others (e.g. heterogeneity across initial arrays vs. test shapes). These and other manipulations suggest that perceptual averaging is well adapted to at least some of the kinds of heterogeneity that are characteristic of real-world visual experience.

43.560 **The weight of the visual world is modified by recent experience : Modeling repetition priming in a partial report task**

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Repetition priming of visual search traditionally refers to the reductions in reaction time when a target, or a target feature, is repeated on consecutive trials. Priming was initially thought to be a facilitated response to the target-defining feature, while repetition of irrelevant target features was thought not to benefit visual search. The simple feature facilitation view has later been contested by results where repetition priming was only observed in response to whole-target repetition and results where search-irrelevant features were primed independently of the target-defining feature. Recent proposals assume that repetition priming operates at multiple levels. Here we focus on two questions: (1) does repetition priming have a purely perceptual component? and (2) how does such a component fit into the TVA framework? (Bundesen, C. 1990. Psychological bulletin and Review, 97, 523-547) In this study we briefly (20-110 ms.) presented subjects with a circular array of 6 digits, one of which was a color singleton target (1T5D partial report), whole report trials (6T) where subjects reported as many uniformly colored digits as possible and single target presentation (1T0D). Non-speeded accuracy tasks were chosen to isolate the perceptual component in repetition priming from response related biases and motor components. Color and position repetition benefits were evident at very brief exposures. The results support the hypothesis that repetition priming occurs for feature processing, while not ruling out repetition benefits at other levels. Furthermore, color repetition was only beneficial when the task required attentional selection. The results were fitted to a TVA-based model from which we provided estimates of weights. The results from the modeling procedure indicate that the perceptual component of repetition priming is best described as a modification of feature weightings by recently attended features.

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Motion: Neural mechanisms and models

Tuesday, May 15, 8:00 - 9:45 am
Talk Session, Royal Palm Ballroom 1-3
Moderator: Bart Krekelberg

51.11, *8:00 am*
A contrast-sensitive, redundancy reduction mechanism acting on MT neurons can explain global motion direction biases without the need for Bayesian priors
John A. Perrone[1](jpnz@waikato.ac.nz), Richard J. Krauzlis[2]; [1]The University of Waikato, New Zealand, [2]Laboratory of Sensorimotor Research, National Eye Institute, NIH, Bethesda, MD.

Introduction: The perceived global direction of moving objects can be influenced by the contrast of the object (Weiss, Simoncelli & Adelson, Nature Neuroscience, 2002). There is currently no detailed, neural-based explanation for how this could occur. Weiss et al., proposed an ideal Bayesian observer model that included a physiologically unspecified 'low speed' prior. We have recently developed a new velocity code for extracting image velocity from small groups of MT neurons (Perrone & Krauzlis, VSS 2011). The code includes a stage of local spatial inhibition between MT neurons designed to reduce the amount of redundant signals passed onto the global motion integration stage (MST). The inhibition is made dependent upon the contrast of the stimulus by exploiting the fact that some MT neurons change their speed tuning (V shifts to □ .5V) at low contrast (Krekelberg et al., J. Neurosci., 2006). An inhibitory signal based on the difference in output from two such MT units tuned to V and 2V will be high at high contrast, but will switch off at low contrast when the input speed is V. Methods: We tested our velocity code using high- and low-contrast rhombus stimuli that have been shown to produce contrast dependent biases in global motion estimates (Weiss, et al., 2002). Results: The model produced contrast dependent estimates of global motion direction that match the perceptual results. Low contrast rhomboids tended to produce estimates orthogonal to the major axis of the rhombus whereas high contrast rhomboids produced estimates closer to the veridical direction. Our simulations indicate that at low contrast the spatial inhibitory mechanisms between MT neurons may be switching off causing an increase in the density of responses signalling motion orthogonal to the edges. Conclusion: Our model provides a biologically plausible mechanism by which the Weiss et al., Bayesian prior could be implemented.

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51.12, *8:15 am*
Synchrony and firing rate modulation in area MT at the time of saccades
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Humans perform about three eye movements per second. The detection of briefly flashed targets around such saccades is more difficult compared to fixation. This loss in sensitivity is typically referred to as saccadic suppression. Because a clear neurophysiologic correlate has not yet been identified, we continue the quest to identify possible neural mechanisms of saccadic suppression. We recorded electrophysiological data in area MT of two macaques while they observed randomly positioned flickering bars and performed optokinetic nystagmus (OKN), a sequence of slow phases interspersed with fast backward eye movements. The OKN was induced by a random dot pattern that moved to the left or to the right and filled the entire screen. We analyzed the firing rate, local field potential (LFP), the power of the LFP, as well as the correlations between the stimulus and the spikes and the correlations between the stimulus and the LFP, all around the time of saccades. The power of the LFP in a frequency band matched to the stimulus frequency showed a large drop around saccade onset, even when the firing rate of individual cells was increased or not modulated. This suggests that a lack of population synchrony may contribute to the reduced detectability of a visual stimulus around the time of a saccade. We also used the polarity of the LFP modulation around saccade onset to putatively assign neurons and LFP recordings to specific layers (supra or infragranular; Murthy and Fetz, JNeurophys 1996). This assignment revealed a layer-specific modulation of firing rate immediately after the saccade. One group of neurons (e.g. in the putative infragranular layers) showed an increase of firing after the saccade, while the other group showed a decrease. We speculate that this may be a signature of feedback modulation enhancing the representation of afferent input.

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51.13, *8:30 am*
Dissociating mechanisms of spatial suppression and summation in human MT: a tDCS study
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Introduction: In visual motion perception, spatial suppression is behaviorally measured as the increase of direction discriminations threshold with the increasing stimulus size. This counterintuitive result likely reflects inhibitory mechanisms within visual area MT (Churan et al., 2008; Tadin et al., 2011). Spatial suppression, however, is observed only for high-contrast stimuli. At low-contrast, stimuli become easier to discriminate as their size increases, a result indicating spatial summation. Here, we aimed to (1) determine whether both spatial summation and spatial suppression are causally linked to MT, and (2) elucidate the role(s) that MT plays in motion summation and suppression. We addressed these questions by interfering with the normal MT functioning using bilateral cathodal transcranial direct current stimulation (tDCS). Methods: Eight subjects performed a motion direction discrimination task in four conditions: small (1.2°) or large (8°) gratings presented at either high-contrast or low-contrast (1cycle/°, 4°/s, foveally presented). Each subject completed three counterbalanced sessions: baseline, cathodal tDCS and sham tDCS. During tDCS sessions participants completed the task three times: pre-tDCS, post-tDCS and 60 minutes post-stimulation. tDCS was delivered bilaterally over each MT for 20 min (2 mA). Results: At baseline, thresholds for large high-contrast gratings were substantially higher than those for small gratings, a marker of spatial suppression. At low-contrast, large moving stimuli were easier to discriminate, indicating spatial summation. Cathodal tDCS affected both spatial suppression and spatial summation, but in different ways. We found a significant improvement in motion discriminations of large, high-contrast stimuli and a significant impairment in motion discriminations of large, low-contrast stimuli. Sham stimulation had no effect. Conclusion: These findings are consistent with the hypothesis that spatial suppression and summation critically and directly depend on mechanisms within visual area MT. Moreover, dissociable effects of tDCS on suppression and summation indicate that MT plays opposite roles in these visual processes.

51.14, *8:45 am*
Recurrent competition explains temporal effects of attention in MSTd
Oliver Layton[1](owl@cns.bu.edu), N. Andrew Browning[1]; [1]Cognitive and Neural Systems, Boston University

Forward navigation in a rigid environment along straight paths without eye movements produces radial optic flow fields. A singularity called the focus of expansion (FoE) specifies the direction of travel (heading) of the observer. Cells in primate visual area MSTd are thought to be heading-sensitive, since they respond to radial fields. Humans frequently shift their focus of attention while navigating, for example, depending on the favorable or threatening context of approaching independently moving objects. Dubin & Duffy (2010, Neuroreport) showed that the spatial tuning curves of MSTd neurons change based on the relative position between an attentional prime and the FoE. Moreover, the peak mean population activity in MSTd retreated linearly in time as the distance between the attentional prime and

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FoE increased. We present a dynamical neural circuit model, based on the ViSTARS model (Browning et al. 2009, Cog Psy), that when given similar inputs demonstrates the linear temporal peak shift observed electrophysiologically when varying the spatial location of attention. The model also qualitatively matches the neuron tuning curves and population activation profiles. After model MT+ dynamically pools short-range motion, model MSTd incorporates recurrent competition between units tuned to different radial optic flow templates, and integrates attentional signals from model area FEF. In the model, population activity peaks indicate when the recurrent competition is most active and uncertainty is greatest about the FoE location. The nature of attention, multiplicative (Martinez-Trujillo & Treue 2004, Current Biology) or non-multiplicative (Womelsdorf et al. 2008, J. Neuroscience), is largely irrelevant, so long as attention has a Gaussian-like profile. Using particular signal functions to modulate the recurrent feedback affords qualitative fits of deflections in the population activity that otherwise appear to be low-frequency noise. We predict that these deflections mark changes in the balance of attention between the priming and FoE locations.

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51.15, *9:00 am*

Adapting to imperceptible multidirectional motion yields perceptible aftereffects: A psychophysical and computational investigation

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It has been shown that humans cannot perceive more than three directions from a multidirectional transparent motion stimulus. However, it remains unknown whether adapting to such imperceptible motion could generate any perceptible motion aftereffects (MAEs). Here, we demonstrate that the visual system integrates local aftereffects over space to produce perceptiple MAE after adapting to the multidirectional motion stimulus. The stimulus contained 260 randomly-oriented, equally-spaced drifting Gabor elements. They were randomly divided into five sets, each of which was assigned one distinct global motion direction. Local velocities of elements within the same set were manipulated so that they were consistent with the set's global velocity. In Experiment 1, we first confirmed that observers were unable to identify any of the five embedded directions in this multidirectional stimulus. We then had observers adapt to this imperceptible pattern, and then indicate the MAE direction perceived on a static test pattern. We found that, when tested with elements taken from multiple sets (the Mixed condition), reported MAE directions were uniformly distributed. However, when tested with elements taken from the same set (the Single condition), observers reported MAE directions mainly 180° away from the set's adapting direction. In Experiment 2, we used complex motion patterns (rotations and expansions) and found similar results. These results show that humans can clearly perceive individual MAE directions after adapting to an imperceptible motion pattern. We developed a two-stage computational model that: 1) computes local MAEs based on adaptation-induced changes in tuning properties of local motion detectors, and 2) averages local MAEs across test locations. Prediction from the model matches well with humans' perceived MAE directions in all experimental conditions. Altogether, our psychophysical and computational results provide evidence for the existence of a mechanism that integrates local aftereffects over space to generate global MAE percepts.

Acknowledgement: This research was supported by NSF grant BCS-0843880

51.16, *9:15 am*

Double dissociation between the extrastriate body area and the posterior superior temporal sulcus during biological motion perception: converging evidence from TMS and fMRI

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Our brains engage numerous regions when exposed to biological motion, with the posterior superior temporal sulcus (pSTS) being the primary locus. However, most of the supporting evidence stems from studies that contrasted intact with position-scrambled point-light animations. This approach leaves unclear the exact functional role of not only this region, but also of other co-activated regions, including hMT+ and the extrastriate body area (EBA). Here, we set out to determine the specific roles of pSTS and EBA during biological motion perception, focusing on walker orientation and walking direction. To obtain converging evidence, we conducted separate TMS and fMRI experiments within the same subjects (N=12). Two separate tasks were used in the TMS study: walker orientation and walking direction. In the orientation task, subjects identified the facing direction of a "point-light" walker (left vs. right). In the direction task, subjects identified walking direction (forward vs. backward). Task performance was compared before and after applying repetitive offline TMS (1Hz) over EBA and pSTS (based on fMRI-guided stereotaxy). In the fMRI study, EBA and pSTS were mapped in separate scans using standard localizers. Subsequently, runs with point-light walkers (2 facing orientations * 2 walking directions) were subjected to Multi-Voxel Pattern Analysis, determining the amount of static (orientation) and dynamic (direction) information present within EBA and pSTS. Both TMS and MVPA revealed a strong double dissociation between inferred functions of EBA and pSTS. Disrupting EBA impaired performance on the walker orientation task, while leaving walking direction performance intact. In contrast, disruption of pSTS processing resulted in the opposite effect ($p<.001$). Similarly, EBA BOLD response revealed significant walker orientation information and no walking direction information, while (again) pSTS BOLD response displayed the opposite pattern ($p<.005$). We provide converging and causative evidence that dissociates EBA (static body processing) from pSTS (dynamic body sequence processing) during action perception.

Acknowledgement: Junior Post-doctoral Fellow Italian Institute of Technology

51.17, *9:30 am*

Neural correlates of perceptually bistable motion-based grouping.

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When four dot-pairs, rotating in phase about their respective pair centers, are arranged in a square configuration, they either group together into a "global" motion percept of two large squares translating along overlapping circular trajectories or appear as a "local" motion percept of four independently rotating dot-pairs (Anstis & Kim, 2011). The global percept is incompatible with, and perceptually very different from, the local percept, although the stimulus remains constant across perceptual switches. This type of motion-based perceptual grouping is interesting, because its output must serve as the basis for computing perceived motion, as global percepts are perceived to move more slowly than local percepts (Kohler, Caplovitz & Tse, 2009). Unlike Kanizsa-style inducers, dot-pairs contain no contours that share orientation with the illusory squares, which severely constrains the neural mechanisms that can be proposed to account for the grouping. Here, we exploited the fact that dot-pairs rotating out-of-phase are less likely to evoke a global motion percept, and presented subjects in the fMRI scanner with in-phase and out-of-phase dot-pairs. At each brief presentation, subjects reported whether their percept was local or global. We applied both univariate GLM analysis and multivariate pattern analysis within pre-defined visual regions-of-interest to find areas that distinguished between the local, rigid global (in-phase) and non-rigid global (out-of-phase) percepts. While we found no univariate effects, the multivariate analysis revealed that early visual (V1-V3) as well as motion sensitive areas (hMT+) carried information about the percepts. Classifying between physical differences in phase was not possible in most of these areas, indicating that image level features did not drive classification. We conclude that motion-based grouping of this type is mediated at least in part by mechanisms within regions of retinotopically organized visual cortex.

Attention: Space, features and objects

Tuesday, May 15, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 4-5

Moderator: Edward Awh

51.21, *8:00 am*

Attentional capture by images that match a conceptual target set

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It is well established that stimuli can capture attention if they possess a target defining feature such as color or motion. The present study explored whether images belonging to a conceptually specified target category, such as Sports equipment can also capture attention. There were 29 different categories, which were used to create 80 trials for each subject. Each subject saw each target image only once during the experiment. In a task involving central RSVP of images and peripheral distractor images (see figure 2), a potent capture effect was found for distractor images containing category relevant versus category irrelevant information. The timing of this capture effect matched that of simpler features from Folk Leber & Egeth (2002), with strong capture when distractors appeared 200ms prior to the target, and weak capture when presented simultaneously with it. A subsequent experiment confirmed that this capture effect is spatially specific. These data suggest that attentional control settings can extend beyond simple features to conceptual categories with novel exemplars.

51.22, *8:15 am*

Visual object categorization: is it indeed an attention-free process?

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Traditional theories of attention typically posit that visual recognition requires focal attention. Accumulating findings in the last decade, however, suggest that real-world objects, relative to meaningless arbitrary items, can be detected and categorized even when presented very briefly at an unattended location. Most of the studies supporting this view of attention-free processing use dual-task paradigms, in which participants perform a highly demanding task at fixation, while simultaneously detecting a pre-specified object category (e.g., an animal or vehicle) at the periphery. A major limitation of this method is that the supposedly 'unattended' peripheral object is in fact a target stimulus, thus participants intentionally allocate attention to its location. To overcome this limitation, we assessed object categorization under conditions in which an object is strictly irrelevant to task-requirements and to response-selection processes. Participants performed a forced-choice classification task of briefly presented pairs of objects (e.g., 'is there a nonsense object in the display, or not'). Within pairs of real-world objects, items either belonged to the same category (e.g., a tiger and a spider; a car and a boat) or to different categories (e.g., a dog and a jeep; a bus and a mouse). When participants performed the task for the two objects in a pair (i.e., both objects were attended), RT for same-category pairs was significantly shorter than for different-category pairs, indicating that object category was registered. When participants were cued to respond to only one of two objects in a pair, such that the other object served as an unattended distractor, no categorical effect was observed. Subsequent experiments revealed that unattended object distractors affect behaviour only if they are relevant to response-selection processes (i.e., compete with response to target). Our results suggest that when unattended objects are strictly task-irrelevant they are not automatically categorized, thus refuting previous claims of attention-free processing.

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51.23, *8:30 am*

It's all in your head: Distractor interference produced by top down expectations.

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In several converging paradigms (flanker, attentional blink, negative priming) we investigated the role of top down factors in processing distractors. We presented ambiguous characters that could be perceived as letters or as digits and found that distractor processing was completely determined by context and expectations and not by stimulus identity. For example, in responding to one of two possible targets (S vs. O) in the flanker task, the same ambiguous distractor, i.e., an S-5 hybrid produced substantial interference in responding to an O target when subjects expected letters as distractors but no interference at all when expecting digits as distractors. Since only top-down information was manipulated whereas stimulus-driven data were kept constant, these findings challenge the view that distractor interference reflects primarily bottom up processing where features of incongruent distractors penetrate and automatically activate the representation of the opposite response category. Furthermore, The present results also support the notion that early visual processing is penetrable to higher cognitive processing since obtaining such context effects on unattended stimuli that the perceiver attempts to ignore rather than process represent more genuine perceptual processes that are less susceptible to post perceptual biases. The nature of interaction between top down and bottom up processes in producing unattended perceptual representations and the notion of cognitive penetrability will be discussed.

51.24, *8:45 am*

Relevance-based control over visual attention is fast and interdependent with stimulus-driven capture

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An object that is relevant to the current task is more readily encoded than a similar, less relevant object (e.g., Wolfe, Cave, & Franzel, 1989). However, it is highly debated whether relevance-based selection is feasible at short exposure durations (e.g., Theeuwes, 2010). It has been argued that high local feature contrast attracts attention independently of task-relevance. Yet, recent studies have provided evidence that effects of task-irrelevant feature contrast interact with the task-relevance of the object in question (Nordfang, 2011). In a new experiment, display size was kept constant while target-distractor configuration was varied (2 targets and 6 distractors vs. 8 targets and no distractors). The targets were letters and the distractors were digits. Displays were postmasked and briefly presented at durations varying from 10 to 100 ms. On some trials, one of the characters (target or distractor) was a color singleton, but the probability that the singleton was a target was just the same as the probability that a nonsingleton was a target. Participants showed significant effects of both feature contrast and task relevance. The probability of correctly reporting a singleton target was significantly higher than the probability of reporting a nonsingleton target. The probability of correctly reporting a given target also was significantly higher for the displays with 2 targets and 6 distractors than for the 8-target displays, revealing selectivity based on task-relevance. This effect was significant even at an exposure duration of 30 ms. Furthermore, as expected from the results of Nordfang (2011), the presence of a singleton distractor decreased the probability of correctly reporting a given nonsingleton target significantly less than did the presence of a singleton target. In summary, the study provided new evidence that both contrast and relevance influence attentional selection at very short exposure durations and the effects of the two factors are interdependent.

51.25, *9:00 am*

Obligatory global feature gain conflicts with task requirements

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It has been shown in both animal and human studies that attentional selection of simple features (e.g. color) enhances processing of this feature across the entire visual field, i.e. it is spatially global. However, it remains unclear whether such global facilitation of features is mandatory or whether it can remain spatially local when the task requires it. To address this question, we presented two completely overlapping fields of red and blue dots, one on each side of a central fixation cross. Participants performed a divided attention task in which they had to attend to the dots of one color or the other in both visual fields concurrently. Trials in which participants attended to the same color on both sides ('attend same') were characterized by good behavioral performance and clear enhancement of steady-state visual evoked potentials (SSVEPs) elicited by attended stimuli. However, when

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the attended color on one side was to be ignored on the other side ('attend opposite'), there was a dramatic drop in behavioral performance and attentional enhancement of SSVEP-amplitudes vanished. A control experiment confirmed that this was due to global spread of feature attention leading to equal enhancement of attended and unattended colors in 'attend opposite' trials rather than a failure to concurrently attend to different colors in the left and right fields. Our results thus demonstrate that spatially global selection of features is a fundamental process which even occurs when it explicitly conflicts with task demands.

Acknowledgement: Deutsche Forschungsgemeinschaft

51.26, *9:15 am*

Attention is drawn spontaneously to regularities during statistical learning

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The visual environment contains widespread regularities, but this structure represents only a subset of the complex and noisy input available at any given moment. The challenge for statistical learning is thus to identify what aspects of the environment to learn about. Here we propose that regularities themselves capture attention, prioritizing their own locations and features for further processing. In Experiment 1, we examined whether regularities cue spatial attention. Observers viewed four simultaneous streams of shapes. Unbeknownst to them, the stream in one 'Structured' location was generated from triplets, while the streams in three 'Random' locations were randomized. To probe spatial attention, we presented occasional search arrays where the target appeared randomly at one of the shape locations. Target discrimination was reliably faster for targets at Structured vs. Random locations, suggesting prioritization of locations containing regularities. To generalize this finding, in Experiment 2 we examined whether regularities cue feature-based attention. Observers viewed a single stream at fixation containing red and green shapes. Shapes in the 'Structured' color appeared in triplets, while those in the 'Random' color appeared in a randomized order. We probed feature-based attention with search arrays that now contained a color singleton: either a distractor or target appeared in either the Structured or Random color. Target discrimination was faster overall for target vs. distractor singletons as expected, but critically, this capture was significantly stronger for Structured color singletons, suggesting prioritization for features of objects embedded in regularities. These findings reveal a new type of automatic orienting to regularities, driven neither by inherent stimulus salience nor by intentional goals, which may in turn encourage further statistical learning about matching locations and features. Such orienting provides both a novel implicit and online measure of statistical learning, and a compelling demonstration of the influence of statistical learning over other parts of cognition.

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51.27, *9:30 am*

Neural measures reveal a fixed item limit in subitizing.

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Humans are endowed with an extraordinary ability to rapidly and accurately enumerate small sets of items, a process known as subitizing. Despite over a century of research, there is still active debate regarding the mechanisms that mediate this ability. For example, some have argued that subitizing reflects the operation of a limited-capacity individuation mechanism that enables concurrent access to a small number of items. However, others have argued that subitizing reflects the operation of a continuous numerical estimation mechanism whose precision varies with numerosity in a manner consistent with Weber's law. Critically, quantitative models based on either of these views can provide a reasonable description of performance on a subitizing task, making it difficult to discriminate between these alternatives solely on the basis of subjects' behavior. Here, we attempted to discriminate between limited-capacity and continuous estimation models of subitizing using neural measures. In two experiments, we recorded EEG while subjects performed a demanding subitizing task and examined set-size dependent changes in a neurophysiological marker of visual selection (the N2pc ERP component) evoked by an array of to-be-enumerated items. We reasoned that if subitizing reflects the operation of a limited-capacity individuation mechanism, then N2pc amplitudes evoked by a subitizing array should reach an asymptotic limit at or near behavioral estimates of subitizing span. In both experiments, N2pc amplitudes increased monotonically within the subitizing range before reaching an asymptotic limit at around 3 items. Moreover, intersubject differences in the location of this asymptote were strongly correlated with behavioral estimates of subitizing span. Thus, neural activity linked with subitizing ability shows evidence of an early and discrete limit in the number of items that can be concurrently apprehended.

Acknowledgement: Supported by NIH R01-MH087214 to E.A. and E.K.V.

Color and light: Surfaces and materials

Tuesday, May 15, 10:45 - 12:30 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Roland Fleming

52.11, *10:45 am*

Estimating material by estimating shape

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An object's appearance depends on a complex interaction of shape, illumination, and material. Despite decades of work, it has proven difficult to build computational systems that estimate these components individually. For example, shape from shading systems are still mediocre even when the illumination and BRDF are precisely specified. At the same time, techniques for material classification in the absence of shape remain limited. We have found that it is possible to make material estimates and shape estimates as part of the same process. Our learning based system is trained on multiple shapes and materials. We have a collection of "blobby" 3D shapes and we render them with multiple "styles," where a style captures the combined effects of illumination and BRDF. For a given patch of surface normals (our choice of shape descriptor) there will be multiple renderings that have different appearances. We build a library of pairings between shape patches and image patches, and then try to solve the inverse problem: estimating the surface normals given the image. This works poorly for an isolated patch, because many things in the world could give rise to similar image patches. Things get much better when we impose consistency across the image, using belief propagation. It is possible to make estimates of material by pooling the votes of multiple patches taken individually. However, the performance improves when the voting is done with the patches that were selected to consistently estimate the shape. Thus, while the system is primarily designed to estimate shape, it automatically gives a good estimate of material as well.

52.12, *11:00 am*

Disentangling 3D Shape and Perceived Gloss

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Recent work has shown that judgments of gloss are distorted by 3D surface geometry. These results reveal consistent failures in gloss constancy, but the cause of these failures remains unknown. We conducted experiments to determine what underlies the effects of 3D surface relief on perceived gloss. In Experiment 1, bumpy surfaces with a fixed gloss level and different levels of relief were rendered in a number of different illumination fields that varied in complexity and direction of the primary light source(s). Surfaces were viewed either with or without binocular disparity. Observers performed paired comparisons of perceived gloss for all stimuli within a given illumination field. The results of these experiments revealed that gloss was strongly affected by 3D surface relief, but that the effects of relief varied significantly across different illumination fields and disparity conditions. Perceived gloss either increased monotonically, decreased monotonicaly, or exhibited strong non-monotonicities as a function of relief height. We hypothesized that all of these effects arose from a number of simple image cues that co-varied with observers' gloss judgments: the contrast, disparity, coverage, and sharpness of specular reflections. To test this hypothesis, we performed an experiment in which independent groups of observers performed paired comparisons and judged each image attribute separately (specular contrast, disparity, coverage, and sharpness). A separate group of observers judged gloss for the same stimuli. Observer's gloss judgments are very well fit by a simple weighted average of the data obtained by observers' judgments of specular contrast, coverage, sharpness, and disparity. Our results suggest that the "contamination" of gloss judgments by 3D shape is caused by the effects shape has on simple image properties that modulate the perception of gloss. Our results suggest a general psychophysical method for testing the role of image cues to material properties.

Acknowledgement: Australian Research Council

52.13, *11:15 am*

Effects of shape and color on the perception of translucency

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Natural materials such as skin, soap, jade, and wax, look translucent because light scatters inside them. Though humans are skilled at discriminating subtle differences in translucent appearance, little is known about translucency perception. We study how translucency perception is related to scattering parameters and object geometry, by measuring perceptual similarities between images rendered with varying scattering parameters, and using these similarities to learn low dimensional embeddings of the images. We compared embeddings for color and gray-scale images in settings where objects were only partly visible. Images of a dragon model were rendered, in gray-scale and color, using 16 different parameters from the spherical polydispersion scattering model, under constant natural illumination. Each observer was shown 1680 ordered triplets of images, and asked to indicate whether the center image was more similar to the left or right image. These paired-comparisons were used with a non-metric multidimensional scaling method to learn 2D embeddings of the data. The 2D embeddings from four observers resembled a U-shaped curve, with images consistently ordered from opaque to translucent. To isolate the effect of different cues in the scene, we repeated our experiments using only images from the opaque side of the curve, masking out either the top- (specular highlights) or bottom-half (see-through effect) of the images with a semi-transparent layer. For color images, the embedding of bottom- and top-masked images had the same shape as under the full-view conditions, while the top-half masked ones had different image ordering. For gray-scale images, the embedding of bottom-half masked images did not have clear structure, while that of top-half masked images was U-shaped but with different orderings from the color case. This suggests that translucency perception depends on shape and there is an interaction between color and shape. The effect of shape on translucency is more significant for gray-scale objects.

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52.14, *11:30 am*

Goop! On the visual perception of fluid viscosity

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Liquids with different viscosities, such as milk, honey and hair-gel, respond to forces in radically different ways. Low viscosity fluids, like water, tend to flow and splash easily, whereas high viscosity fluids, like melting glass, tend to ooze slowly into distinctive clumps. These tendencies lead to strikingly different visual appearances, and in everyday life we readily distinguish between different materials based on the way they flow and change shape over time. Despite this, very little is known about how the brain estimates and represents the properties of fluids. Here, we use computer simulations of liquids with different viscosities to study the visual estimation of viscosity. This allows us to parametrically vary the material properties of the fluid while holding constant all other aspects of the scene (the fluid's volume, initial position, velocity, and optical surface properties), and allows us to make detailed measurements of the fluid's behaviour to correlate with perception. The simulated fluid flowed out of a pipe and fell into a rectangular container. In addition to the viscosity, we also varied the height of the pipe (which affects momentum at initial impact) and the presence of a spherical obstacle in the fluid's path. Using rating scales and maximum likelihood difference scaling (MLDS) we measured a 7-point psychophysical function relating the physical viscosity coefficient (across 7 log units) to perceived viscosity. We find the function is surprisingly close to linear and that subjects already have a strong impression of the viscosity only a few frames after initial impact. We compared performance to a number of 2D and 3D measurements derived from both optic flow and surface geometry. Together these analyses suggest a number of simple heuristics that the visual system could use to estimate viscosity from the way fluids move, and settle into specific shapes.

52.15, *11:45 am*

Adaptation reveals frequency band based inferences of material properties

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Rapid and reliable identification of material properties is important for successful interactions with the environment. Real materials exhibit characteristic configurations of low-level features and it is possible that features corresponding to particular properties are present generically and are stored as knowledge by human observers. We demonstrated at VSS2011, that some common properties perceivable from images of fabrics can be altered by increasing or decreasing the relative energy in specific spatial-frequency bands of the amplitude spectra. This result suggests that simple neural "detectors" for material properties could just combine the outputs of sets of V1 frequency-selective neurons. Can such detectors be revealed through selective adaptation? If observers adapt to a specific frequency-band, thus shifting the balance of sensitivities to other parts of the spectrum, does that shift their judgment of the associated material property? Using frequency-bands identified by our image analyses, we answer these questions for the fabric properties of volume, roughness, and thickness. For test stimuli, we used images of fabrics, along with two versions of each image with increased relative energy in the specific frequency band (constant total energy), and two with decreased relative energy. Baseline psychometric functions for each property were measured by comparing the original image side-by-side with its manipulated or unaltered version. During adaptation, band-pass-filtered dynamic white noise patches were presented on the location of the original image, and complementary notch-filtered dynamic noise patches on the location of the comparison images. The post-adaptation psychometric curve was measured by interleaving adaptation and test presentations. As predicted for each adaptation frequency-band, observers judged fabrics as having systematically less surface volume, softer texture, or thinner weave/knit than the original percept. The results demonstrate that observers directly use broad-band spatial frequency information in perceiving material properties, and suggest that V1 neurons transmit spatial-frequency signals in parallel for material perception.

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52.16, *12:00 pm*

Real world colour constancy – the effect of surface material

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The visual appearance of real world objects depends on their reflectance properties, illumination and geometrical factors. We asked how human colour constancy performance deals with the depth-mesostructure of surfaces, which may provide additional cues or, alternatively, worsen colour constancy. In our experiments we presented samples (circular patches, 90 mm) of different materials (paper, fur, tile, cloth), each mounted on a black sample holder (front 30 x 15 cm, 60 deg slope) and presented in the middle of a black viewing box (1.0 x 1.0 x 0.8 m). All samples appeared nearly achromatic under daylight. The samples and the box were illuminated by a computer controlled, calibrated LCD-projector (Panasonic PT AE 1000E) which was mounted above the observers' head. The observers (2 male, 2 female) viewed the samples frontally (viewing distance 90 cm), either with their head fixed or while making sideway movements with their upper body. The chromaticity of the standard illuminant was D65, the equiluminant test-illuminants were chosen from one of the cardinal axes. After viewing the samples under the standard illuminant for 15 s, the respective test-illuminant was presented for 5 s. Colour constancy was quantified by an achromatic setting method, whereby the degree of colour constancy was calculated from the shift of the achromatic colour locus associated with the illumination change (for illuminant D65, the achromatic colour locus of all samples was within 1 Delta EUV of the colour locus of D65). In the fixed-head condition, we found no differences in the amount of colour constancy achieved for the different materials. However, colour constancy for the sample with the most depth-mesostructure (fur) was significantly increased by selfmotion of the observer. We discuss the possible exploitation of cues from selfmotion and the mesostructure of the material.

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52.17, *12:15 pm*

Surrounding colours influence judgments of surface lightness

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If we were to consider the light reaching our eyes from every surface in isolation, we would be unable to distinguish a white surface under dim illumination from a grey surface under bright illumination. Comparing light reflected by many surfaces helps us to make this distinction. For instance, if a neighbouring surface clearly reflects more light than the surface of interest, the surface of interest cannot be white, because a white surface reflects most of the light that falls on it, so it should be the brightest surface (at least when only considering diffusely reflecting surfaces under uniform illumination). We here examine whether people consider surfaces' colours within this kind of reasoning. If a neighbouring surface reflects a similar amount of light as the surface of interest, but the light that the neighbouring surface reflects is clearly coloured, the surface of interest is again unlikely to be white, because chromaticity is the result of surfaces reflecting light of different wavelengths to different extents, so the intensity of the illumination must be higher than that of the light from the neighbouring, coloured surface. We presented targets on backgrounds with matched average luminance and chromaticity, and matched variability in luminance and chromaticity, but that differed in whether the brightest parts were coloured or not. A staircase procedure was used to find the luminance at which subjects were equally likely to judge the target to be grey and white. We found that this occurred at a higher luminance when the brightest parts of the scene were coloured. Thus, when judging a surface's lightness, people consider that the illumination must be brighter than the light from the brightest surface if the brightest surface is coloured.

Visual search: Context, working memory, categories

Tuesday, May 15, 10:45 - 12:30 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Gregory Zelinsky

52.21, *10:45 am*

The guidance of attention is dominated by task relevance and not simply maintenance in working memory

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The evidence is mixed as to whether attentional biases caused by a visual working memory (WM) representation depend on whether or not that representation is task relevant. Moreover, recent work shows long-term memory templates quickly begin guiding attention when searching for the same target over trials. In many laboratory paradigms, the target representations that guide attention may therefore not be maintained in WM at all. Our goal was to develop a paradigm for measuring the effect of task-relevant and task-irrelevant visual WM representations on attention. Participants searched 6-item arrays for targets while maintaining in WM the search color and another color for a subsequent memory task. This ensured task-relevance was not confounded with representation in WM versus long-term memory. In addition, we removed bottom-up differences between task-relevant and task-irrelevant search items by randomizing the target and memory colors and focusing on the first saccade to ensure all items were an equivalent distance from the current fixation. We tracked observers' eye movements to the task-relevant search target, the task-irrelevant memory match, and distractors during search. First saccades were strongly biased to the task-relevant WM representation (i.e., the target) over the task-irrelevant memory match (respectively 80.9% vs. 5.9%, $p < .0001$). A control condition ensured that this was not due to differing strengths of the two WM representations. We also found a weak, but significant prioritization of the task-irrelevant WM matches over the other distractors whether or not the search target was present (ps <.05). This demonstrates that the strong bias to task-relevant WM matches is not due to a slight competitive advantage over task-irrelevant WM matches, but that the top-down attentional control from task-relevant working memory templates is qualitatively different than an automatic influence of WM representations on attention.

52.22, *11:00 am*

Attentional guidance by working memory overrides saliency cues in visual search

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Visual search is influenced by a variety of factors, including how much the target stands out (i.e., its salience) and whether it is currently relevant (i.e., is it in working memory?). The contents of working memory are known to influence attention in simple visual search (Soto, Hodsoll, Rotschtein, & Humphreys, 2008). Furthermore, this memory influence likely occurs early in visual processing (Soto, Humphreys, & Heinke, 2006), as it can enhance efficient 'pop-out' search—wherein salient targets are detected almost automatically. Here we show that memory guidance can not only enhance but also reverse the capture of attention by visual salience. In a dual-task paradigm that combined working memory and multiple-target visual search, participants were first instructed to remember the rotation and orientation of a 'T' for a memory test at the end of the trial. During the retention interval, participants searched for target 'T's amongst distractor 'L's. Targets were either relatively dark, which made them highly salient against a white background, or relatively light and low-salient. In Experiment 1, working memory significantly guided search such that when the memory item matched a target, participants were more likely to find that specific target first, regardless of salience. Importantly, when the memory item did not match either target, participants found the high-salient target first, in keeping with a classic saliency effect. These results showed that the saliency effect was reversed via working memory biases. In Experiment 2, we amplified the saliency effect, such that the high-salient target was even easier to find. Participants were strongly biased to find the high-salient 'pop-out' target first, yet this saliency effect was attenuated when the memory item matched the low-salient target. Collectively, these findings indicate that the deployment of attention in visual search is modulated by a balance between memory guidance biases and saliency cues.

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52.23, *11:15 am*

Category-based attention shifts tuning toward the target object category during natural visual search

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Humans can effortlessly identify objects in natural scenes, and they can shift attention rapidly between objects in a scene. We recently showed showed that much of neocortex is selective for object categories (Huth et al., SFN 2010). How are these categorical representations modulated when attention is directed toward specific categories? Neurophysiological studies in area V4 have shown that feature-based attention causes shifts in tuning toward the attended feature (Mazer et al., 2003; David et al., 2008). Therefore, here we sought to determine whether category-based attention shifts object category tuning toward the attended category. Human subjects viewed natural movies for 60 minutes while fixating steadily. Blood-oxygen level-dependent (BOLD) responses were recorded continuously using whole-brain fMRI. Two category-based attention tasks alternated in ten minute blocks: search for "humans" and search for "vehicles". Subjects depressed a button whenever an exemplar of the target category appeared in the movie. Categorical tuning was estimated for each voxel using the modeling approach developed in our earlier studies. First, the objects in each one-second movie clip were labeled using 900 categories drawn from WordNet. Then regularized linear regression was used to estimate categorical tuning for each voxel under each condition of category-based attention. We find that category-based attention causes many voxels to shift their tuning toward the target object. These shifts cannot be described by simple additive (baseline) or multiplicative (gain) changes at the level of single voxels. Large tuning shifts were detected in most of occipito-temporal cortex, and in fronto-parietal brain areas commonly assumed to be a control network of attention. These data demonstrate that category-based attention shifts tuning dynamically to more closely match the attended object category. This pattern suggests that the visual system implements a matched filter scheme to optimize processing of behaviorally-relevant objects during natural vision.

 See page 3 for Abstract Numbering System

Acknowledgement: NIH Grant EY019684-01A1

52.24, *11:30 am*

Simultaneous Control of Attention by Multiple Working Memory Representations

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Working memory representations play a key role in controlling attention, making it possible to shift attention to task-relevant objects. Visual working memory has a capacity of 3-4 objects, but recent studies suggest that only one representation can guide attention at a given moment. To test this, we recorded eye movements during a visual search task in which observers searched for a Landolt-C target in an array of 24 (Experiment 1; half red, half blue) or 32 (Experiment 2; equal numbers of red, yellow, green, and blue) items. Experiment 1 was designed to identify behavioral signatures of template use and template switching. There were three cue conditions in which a color cue at the beginning of the trial validly specified the target color on 100% of trials (100/0 condition), 80% (80/20 condition) or 50% (50/50 condition). The 80/20 condition encouraged observers to begin searching cued-color items, but then switch to searching the uncued-color items if the target had not been located, whereas the non-predictive, 50/50 condition encouraged observers to search randomly across both colors. When observers implemented a single color template in the 80/20 condition, they sequentially searched many consecutive items of a color (long run lengths), and they exhibited a delay prior to switching gaze from one color to another (switch cost). Experiment 2 probed the ability to employ two templates simultaneously. Observers were cued to search two out of the four colors present, and they were instructed to search the two colors either sequentially or simultaneously. In the sequential condition, observers again exhibited long run lengths and a switch cost. In contrast, when searching two colors simultaneously, observers exhibited short run lengths and no switch costs, consistent with the simultaneous guidance of attention by the two cued colors. Thus, multiple working memory representations can guide attention concurrently.

52.25, *11:45 am*

Modeling Guidance and Recognition in Categorical Search: Bridging Human and Computer Object Detection

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Search consists of a process that compares a target representation to blurred patterns in the visual periphery for the purpose of generating a guidance signal, and a recognition process that verifies targets or rejects distractors, usually after fixation by gaze. Do these component search tasks use the same visual features? We addressed this question by training several SVM-based classifiers to describe both behaviors. Observers did a present/absent categorical search for a teddy bear target in four-object arrays. Target-absent trials consisted of random category objects ranked as visually target-similar, target-dissimilar, or medium-similarity, as described in Alexander & Zelinsky (2011, JOV). Accuracy was high on target-present (95.3%) and target-absent (97.9%) trials, and guidance was quantified as the object first fixated during search. First fixations were most common on targets (79.4%), followed by target-similar (65.5%), medium (12.4%), and target-dissimilar (5.7%) distractors. Bear/non-bear classifiers were trained using features ranging in biological plausibility (V1, C2, SIFT-BOW, SIFT-SPM), with each feature tested separately and in combination with color. Training and testing was done on non-blurred and blurred versions of objects in separate conditions. Objects were blurred using TAM (Zelinsky, 2008, Psychological Review), which approximated an object's appearance in peripheral vision before the initial eye movement. Accuracy and guidance patterns were modeled almost perfectly by an SVM using C2 and color features; a simple and biologically-plausible feature outperformed state-of-the-art computer vision features in a head-to-head comparison. These results were obtained by training on non-blurred objects and testing on blurred objects (pre-fixation viewing conditions existing at guidance) and non-blurred objects (post-fixation viewing conditions existing at recognition)—training on blurred objects resulted in worse guidance fits. Moreover, adding color to the C2 feature improved fits to both guidance and recognition, although SVM used color more for guidance. Despite different viewing conditions, these findings suggest that search guidance and recognition may use the same features, albeit with different weightings, and may therefore be more related than previously believed.

Acknowledgement: This work was supported by NIH grant R01-MH063748 to GZ.

52.26, *12:00 pm*

Object-based Implicit Learning in Visual Search: Perceptual Segmentation constrains Contextual Cueing

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In visual search, detection of a target is faster when it is presented within a layout of nontarget items that is repeatedly encountered, indicating that contextual invariances can guide selective attention (contextual cueing; Chun & Jiang, Cogn. Psychol., 1998). However, perceptual regularities may interfere with contextual learning; for instance, there was no contextual facilitation when four nontarget items formed a global square-shaped grouping, even though the shape was predictive of the target location (Conci & von Mühlenen, Atten. Percept. Psychophys., 2009). Here, we extend our previous findings by showing that contextual cueing can reliably occur for targets located within the region of a globally segmented object, but not for targets presented outside of the object's boundaries. Four experiments demonstrate an object benefit in contextual cueing, with a modulation of context-based learning by relatively subtle grouping cues including closure, symmetry, and spatial regularity. Moreover, the lack of contextual cueing for targets located outside of the segmented region was due to an absence of (latent) learning of contextual layouts, rather than to attention being biased towards memory-based retrieval of only the item layout in the area defined by the grouped region. Taken together, these results indicate that perceptual segmentation provides a basic structuring within which contextual scene regularities can be acquired. This in turn argues that contextual learning is fundamentally constrained by object-based selection.

Acknowledgement: Deutsche Forschungsgemeinschaft (DFG) Project Grant (CO 1002/1-1)

52.27, *12:15 pm*

Contextual cueing-associated activation in working-memory-supporting brain areas

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Contextual cueing is regarded as an implicit form of spatial learning which occurs in repeated search displays, typically in the absence of explicit recognition. However, recently, there have been behavioral studies suggesting that the search facilitation observed in repeated displays depends on visuospatial working memory resources. Working memory appears to support the expression of learning rather than the learning itself (Manginelli et al., 2011; Vickery et al., 2010). Here, we used fMRI to investigate the neural basis of these processes. To this end, we first looked for brain areas in which the BOLD response in a visual working memory task reflects working memory capacity (Todd & Marois, 2004). Using these areas as a mask, we looked for activation that is correlated with the individual size of the contextual cueing effect in visual search. Such a correlation was observed along the banks of the descending segment of the left intraparietal sulcus. Furthermore, increased activation for repeated versus novel search displays was observed in ventral occipitotemporal cortex.Thus, the cortex along the left posterior intraparietal sulcus became less involved in visual search the better the repeated displays were learned, whereas ventral occipitotemporal areas showed a consistent increased response to repeated displays. The latter may reflect the increased demands on visuospatial working memory that is required for successful expression of visuospatial context learning, whereas the former appears to reflect the more efficient search in learnt displays. References: Manginelli, A. A., Geringswald, F. & Pollmann, S. (2011). Visual search facilitation in repeated displays depends on visuospatial working memory. ExpPsychol, Jul 18:1-8. [Epub ahead of print] Todd, J.J., Marois, R. (2004). Capacity limit of visual short-term memory in human posterior parietal cortex. Nature 428(6984):751-754. Vickery, T.J., Sussman, R.S., Jiang, Y.V. (2010). Spatial context learning survives interference from working memory load.J Exp Psychol Hum Percept Perform 36(6): 1358-1371.

Acknowledgement: DFG PO 548/6-2

Tuesday AM

Tuesday Morning Posters

Face perception: Emotion

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

53.301 **Dissociating conscious perception of fearful faces and bodies by transient inhibition of right pSTS**

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Smooth processing of the affective information conveyed by the face and the body is essential for fluent social communication, but the relative importance and the neurocorrelates of the perception of facial and bodily expressions are still poorly understood. We contrasted images of fearful and neutral bodily and facial expressions with houses using a binocular rivalry design and measured the perceptual sensitivity to either stimulus class after inhibition of neural activity in the right posterior superior temporal sulcus (r-pSTS) and vertex with offline 1 Hz rTMS. The results showed a clear pattern in which the transient lesion of r-pSTS facilitates the conscious percept of fearful bodies and suppresses that of fearful faces while leaving unaffected the perception of their neutral expression. Thus, r-pSTS plays a dissociated role in processing facial and bodily emotional expressions. We propose that the differential adaptive function of perceiving and responding to facial and bodily fearful expressions may be reflected in a dissociation of the link between pSTS and emotion and action related systems. Posterior STS seems to regulate action programming for socially relevant stimuli and possibly plays a major role in behavioural control.

53.302 **The Role of Facial Context in Affective Categorical Perception of Simple Geometric Shapes**

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Facial expressions are important visual cues for affective perception. Previous studies have used schematic faces that were assembled from simple geometric shapes to investigate emotion perception. Moreover, some simple noncontextual shapes, such as a downward pointing triangle, are perceived as threatening and capable of activating the neural circuitry underlying threat detection (Larson et al., 2008). However, recent behavioral and electrophysiological evidence shows that shape features underlying threatening faces can improve visual search performance when and only when they are interpreted as a facial component (Weymar et al., 2011). How may facial contexts modulate the affective perception of simple shapes? We generated a series of simple geometric shapes that varied in roundness (triangle/triangle-like ellipse/circle-like ellipse/circle), orientation of the acute angle (downward/upward), and color (black/white). Being part of a fictitious treasure-hunting scenario, participants were asked to make preference choices of a direction marked with one of the shapes that were described above. The effect of simple geometric shapes on affective perception was replicated: participants tended to avoid sharp angled and downward-pointing shapes, especially when the shapes were presented in black. However, we found no categorical boundary between "good" and "bad" shapes. In a follow-up experiment, we measured participants' preferences of schematic faces with the same simple geometric shapes placed in the mouth position. In this case, the affective effect of the shapes reversed: participants preferred the schematic face with a downward-pointing and less rounded mouth. No effect of color was found in this context. Additionally, our results suggest a categorical boundary between "good" and "bad" schematic faces. In summary, affective visual perception of simple shapes changes with the addition of a facial context, suggesting that face processing may play a distinct role in affective categorical perception.

53.303 **Emotional vs. Linguistic Salience in Audiovisual Integration**

Theresa Cook[1](tcook002@ucr.edu), James Dias[1], Lawrence Rosenblum[1]; [1]University of California Riverside

Evidence suggests that humans perceptually prioritize and crossmodally integrate both emotional and linguistic information from speaking faces. We compared the perceptual salience of emotional and linguistic speech information in 2 experiments involving crossmodal congruence judgments. We recorded the audiovisual speech of 2 actors saying 5 word-pairs (selected for semantic neutrality and comparable lexical frequency) neutrally and in 3 emotions (happy, angry, sad). Each member of a word-pair differed from the other on 1 visible phoneme (e.g. camper vs. pamper). In Experiment I, participants judged which of two stimuli were more audiovisually congruent. On each trial, 1 stimulus was fully audiovisually congruent [AC] (e.g. participants heard "camper" in a happy voice and saw "camper" articulated with a happy facial expression), while the other stimulus was either a) emotionally congruent and linguistically incongruent [EC] or b) linguistically congruent and emotionally incongruent [LC]. Participants selected AC stimuli as more audiovisually congruent significantly above chance, $t(19)=9.292$, $p<.001$, and individuals performed as well on AC/EC trials as on AC/LC trials, $t(19)=1.295$, $p=.211$. In Experiment II, half the trials contained 1 AC stimulus compared against a stimulus that was both linguistically and emotionally incongruent [NC], while the other half contained 1 EC compared against 1 LC stimulus. Participants again selected the AC stimuli significantly above chance, $t(19)=45.366$, $p<.001$, and exhibited previously undemonstrated distinct intersubject preferences for selecting either emotionally, $n=11$, $M=73.6\%$, $SD=11.1$, or linguistically, $n=9$, $M=75.1\%$, $SD=10.3$, congruent stimuli as the best audiovisual match. Though Experiment I demonstrated the two types of stimuli are equally discriminable, Experiment II revealed strong individual differences in perceptual prioritization of emotional and linguistic information for the purposes of choosing the best crossmodal match. Results suggest that, in audiovisual integration, the perceptual salience of emotional and linguistic speech information varies among perceivers.

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53.304 **Approaching the good and avoiding the bad is more automatic for emotional words than for emotional faces**

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To approach or to avoid is a fundamental decision each cognitive agent has to make in their daily routines. Previous studies have showed that emotional valence of stimuli is bidirectionally linked to behavioral dispositions. Positive valence facilitates approaching and negative valence facilitates avoiding, meanwhile people tend to give more positive evaluations during approaching but more negative evaluations during avoiding. However, it is still controversial whether this link is automatic and independent of evaluation. In the present study we adopt the implicit association test (IAT) to explore the possible automatic link between behavioral tendencies and emotional valences. In experiment 1, participants were required to categorize happy faces versus disgusting faces, or approaching arrows versus avoiding arrows. They were able to categorize the items faster in the compatible condition (e.g., happy faces and approaching arrows were assigned to left hand while disgusting faces and avoiding arrows were assigned to right hand) compared with the incompatible condition (e.g., happy faces and avoiding arrows were assigned to left hand while disgusting faces and approaching arrows were assigned to right hand). In experiment 2, participants were still asked to categorize approaching arrows versus avoiding arrows, but to make gender judgments (male versus female) for the same faces used in experiment 1. The irrelevant emotional expressions turned out to have no effects on categorization. In experiments 3 and 4, emotional faces were replaced by emotional words and participants were demanded to categorize the valence of the word or whether the word describe a person or an object besides the arrow categorization. In both experiments, we found a strong link between approach/avoidance and positive/negative

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valence of the emotional words, regardless their task relevance. It seems that emotional words convey more strong cues for us to make approach/avoid decisions than emotional facial expressions.

53.305 **The Role of Familiarity and Sex in Recognizing Spontaneous Emotional Expressions**

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The purpose of this study was to explore how familiarity with a face and the sex of the recognizer might interact in an emotion recognition task. Within the field of emotion recognition there have been numerous studies exploring the role of familiarity in emotion recognition. It seems plausible to propose that the more familiar someone is, for example a friend or family member, the more likely that the person's expression will be identified accurately. However, numerous studies using posed expressions have found no improvement for recognizing emotions of familiar faces compared to unfamiliar faces. Another factor that may affect a person's skill at recognizing emotions is sex. Prior studies have indicated that women tend to identify emotions more accurately than males (Hoffman, et al., 2010; Montirosso, et al., 2009; Wagner, 1990). We utilized genuine, spontaneous emotional expressions. Participants were familiarized with happy expressions and tested with the following expressions: confused, disgust and neutral. The type of emotional expression (confused, disgust, or neutral) was significant for male and female participants in both accuracy and response times. Confusion was the emotion most difficult to identify for males and females. Although a main effect of familiarity was not observed, female participants showed a two-way interaction between expression type (familiar or unfamiliar) and emotional expression (confused, disgust or neutral). Females showed an advantage of familiarity when labeling confused faces. These results indicate that females are better able than males to take advantage of familiarity with a face when recognizing emotions, but only when the emotion is difficult to identify. Thus, the advantage engendered by being familiar with a face may be specific to conditions where recognition is more challenging and the recognizer is able to take advantage of previous experience.

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53.307 **The effect of orientation and stimulus duration on older and younger adults' ability to identify facial expressions.**

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In younger adults, certain facial expressions (e.g. happiness) are recognized easily, while others (e.g. fear and surprise) are not (Palermo and Coltheart, 2004). Previous results suggest that older adults show overall recognition deficits and qualitatively different patterns in the particular expressions that are most difficult to identify (Ruffman et al., 2008). In the current study, 23 younger (18-33 years old) and 23 older (60-80 years old) adults performed a 4AFC (angry, fearful, happy, sad) facial expression categorization task that varied face orientation (upright/inverted) and stimulus duration (100, 500, 1000ms). For both groups, happiness was the easiest expression to identify, and fear and sadness were the most difficult and most frequently confused. For upright faces, there was no age difference in response accuracy but response latency was longer in older subjects. For inverted faces, older adults showed lower accuracy and longer latencies for expressions of anger, fear, and sadness. Recognition of inverted happy faces was spared in older adults for accuracy, but not response latency. At all stimulus durations, older subjects were less accurate than younger subjects for angry and sad faces, but accuracy for happy faces was unaffected by age. The pattern of relative difficulties was the same in each age group at both orientations and all stimulus durations. Furthermore, there was no age difference in the pattern of response confusions. However, when subjects were asked to classify neutral faces, younger subjects were more likely to respond angry or fearful than sad, while the order was reversed for older subjects. Our results suggest that, in general, older individuals process expressive faces in a qualitatively similar way to their younger counterparts, but are less efficient at extracting the diagnostic information. Age-related deficits observed in previous studies may reflect a general decrease in processing efficiency, rather than facial expression identification per se.

53.308 **Do Children Recognize Dynamic Emotional Expressions Better than Static Ones?**

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Adults are more likely to attribute the expected emotion to a facial expression presented as a dynamic video clip than one presented as static photograph (Bould, Morris & Wink, 2008). However, prior research with preschoolers found no such benefit; 2- to 4-year-olds were no more likely to attribute the expected emotion to dynamic expression than to a static one (Nelson & Russell, 2011). It is possible that preschoolers simply have too little experience with expressions to find a benefit in dynamic presentations, but older children may respond more like adults. We presented 48 children (4- to 7-year-olds) with both static and dynamic expressions. The dynamic expressions were created by a professional actress and contained several emotion cues to provide children sufficient emotional information; the actress simultaneously displayed facial, postural, and vocal cues. Two sets of static facial expressions were also presented. One set was posed by the same actress featured in the dynamic expressions and the other set was a standardized set of expressions previously published (Tracy, Robins & Schriber, 2009). Basic (happiness, sadness, anger, fear, surprise, and disgust) and social emotions (embarrassment, pride) were presented. Children's attributions varied with age $F(1, 46) = 25.89$, $p < .001$, and with emotion $F(7, 322) = 47.02$, $p < .001$. However, like preschoolers, 4- to 7-year-olds were no more likely to attribute the expected emotion to the dynamic expressions as they were to the static expressions, $F(2, 92) = .39$, $p = .67$. These data suggest that children under the age of seven years do not find the presentation of dynamic emotional expressions to be beneficial in attributing emotions, despite the dynamic nature of expressions seen in daily life. Finding a benefit in dynamic expressions may be a later-emerging skill, one that developing between late childhood and adulthood.

53.309 **Dynamic and static expressions of emotion are recognized with equal efficiency**

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Natural human facial expressions of emotion are dynamic events that progressively unfold over time. The question of whether humans can better recognize dynamic than static expressions has been a source of recent debate (e.g., Edwards, 1998; Ambadar, Schooler & Cohn, 2005; Fiorentini & Viviani, 2011; Landers, Christie & Bruce, 1999). Here, we take a novel approach to this issue by asking: 1) Does the information contained in a dynamic facial expression differ from that of a static expression? 2) How does the information content in dynamic expressions evolve over time? and 3) How efficiently do human observers make use of information when recognizing dynamic versus static facial expressions? To answer these questions, we measured both human and ideal observer contrast energy thresholds for recognizing dynamic and static facial expressions of 8 human actors (4 male, 4 female) making 6 different expressions of emotion (anger, disgust, fear, happiness, sadness, surprise). Dynamic stimuli evolved from a neutral to a full expression of emotion over the course of 30 frames (~1 second). Corresponding static stimuli were created by repeating the final frame of each dynamic stimulus for 30 frames. Ideal observer simulations revealed significantly lower thresholds for static than dynamic expressions, indicating more information was available in the static than the dynamic expressions. Additionally, a frame-by-frame ideal observer analysis of the dynamic expressions revealed a monotonic decrease in ideal thresholds across frames, indicating that the amount of information available at a given moment during the production of an expression systematically increased over time. Similar to the ideal observer, human thresholds were significantly lower for static than dynamic expressions, yielding efficiencies (ideal/human thresholds) that were nearly identical across conditions. These results support the idea that the presence of dynamic cues offers no discernible processing efficiency advantage for human observers when recognizing facial expressions of emotion.

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53.310 The development of the ability to process facial emotion in infancy.

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The purpose of the study was to explore visual scanning behavior of expressive faces in 4- and 8-month-old infants. Unfants were presented with expressive photographs (happy, angry, disgusted, fearful and sad) of the female and male faces. Eye-movements were recorded and transformed to match a prototypical face, so that to finely allow seeing which facial parts were focused according to trials and facial expressions. The results indicated that infants paid attention to different facial parts according to the emotions expressed by the faces, the features associated with facial actions during emotion expression being more specifically focused. Furthermore, the temporal course of the visual exploration indicated that, after a common pattern with fixations the center of the faces, the sequence of the exploration of the different facial features varied according to the expressions. The implications for the study of the development of facial emotion understanding in infancy are discussed.

53.311 Emotion Perception by Recently Incarcerated Males

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Rapid and accurate detection of threatening stimuli is essential for survival. Past research supports enhanced visual sensitivity to threatening stimuli including angry faces (e.g., Horstmann, 2009) and angry point-light walkers (Chouchourelou et al., 2006). Experiences in hostile home environments alter visual sensitivity to angry faces in young observers (Pollak & Sinha, 2002). To determine whether hostile experiences during adulthood impact emotion perception, we conducted a visual search and a point-light walker detection task with threatening and non-threatening emotional stimuli. The two subject populations were 40 typical Rutgers University undergraduates and 98 recently incarcerated male parolees (mean age = 38.3 years, mean time incarcerated = 6.41 years). Parolee charges included armed robbery, weapons possession and assault. A standard visual search task was conducted with emotional (angry, happy, neutral) schematic faces. Target and distractor faces were randomly located within a 3 by 4 matrix with set sizes of 3, 6, and 12. Half of the trials contained an oddball face and half did not. Across trials, subjects reported whether or not (2AFC) there was an oddball face. A point-light walker detection task was also conducted in which an emotional walker (angry, fearful, happy, neutral) was presented coherently or scrambled within a point-light mask. Subjects reported whether or not (2AFC) a coherent walker was present in each display. In both studies, observers were never asked to note or assess the emotional content of the stimuli. In the visual search task, parolees detected happy oddball faces faster than angry or neutral oddball faces while typical observers showed the classic anger superiority effect. Similarly, parolees were most accurate in their detection of happy point-light walkers while typical observers were best able to detect angry walkers. These convergent results suggest that adult experiences in traumatic environments can dramatically alter percepts of emotional faces and bodies.

53.312 Individual differences in somatosensory processing and the recognition of complex emotional states

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Simulation theories of social cognition propose that to recognize the facial expressions of another person, we use our own somatomotor representations of that facial expression (Adolphs, 2002). Based on this theory, one might predict that individual differences in the ability to recognize emotional states are related to individual differences in sensitivity to somatosensory input, such as tactile discrimination ability and sensitivity to visual-tactile integration (or visual-tactile integration). To test these hypotheses, we administered the Reading the Mind in the Eyes test (RMIE; a measure of recognition for complex emotional states; Baron-Cohen et al., 2001), a two-point discrimination test, and a rubber hand illusion induction procedure. In the rubber hand illusion, synchronous brush strokes are administered to the participant's hand and a rubber hand to induce a subjective feeling of body ownership of the rubber hand. Critically, individuals vary in their susceptibility to this illusion: approximately 40% of individuals eventually experience the strong sense that the rubber hand is their own hand (Botvinick & Cohen, 1998). The illusion is putatively related to visual-tactile integration, as it is disrupted by asynchronous stimulation of the participant's hand and the rubber hand (Tsakiris & Haggard, 2005). In a sample of 55 individuals, we found that two point discrimination abilities predicted RMIE scores ($r = 0.34$, $p < 0.01$). Susceptibility to the rubber hand illusion during synchronous stimulation also predicted RMIE scores ($r = 0.35$, $p < 0.01$). This relationship was specific to synchronous stimulation, suggesting that the relationship between RMIE scores and susceptibility to the rubber hand illusion was related to visual-tactile integration as opposed to reporting bias or suggestibility. Our findings indicate that recognition of complex emotions is related to both tactile discrimination ability and sensitivity to bottom-up cues driving visual-tactile integration, supporting a relationship between somatosensory processes and social perception.

Acknowledgement: National Science Foundation Graduate Research Fellowship

53.313 Sad Faces and Fearful Bodies: A test of two models of emotion perception

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Perception of facial displays of emotion is influenced by context; error rates and reaction times increase when the emotion displayed by the face (e.g., fear) is incongruent with the emotion displayed by the body (e.g., anger) (Meeren et al., 2005). Two models of emotion perception invoke different mechanisms to explain context effects. Although both models predict that congruency effects will be maximal when emotions are similar, they do not always agree on which emotions are most similar. To compare the predictive validity of these two models we measured context effects for three emotions for which the two models make different predictions: sad, anger, and fear. Whereas the Dimensional model predicts largest effects when fear and anger are paired because both are negatively valenced and high in arousal, the Emotional Seed model predicts largest effects whenever fear or anger are paired with sad because sad faces are more physically similar to anger or fear faces than anger and fear faces are to each other (Susskind et al., 2007). Adults categorized each facial expression when presented on congruent and incongruent bodies. They were instructed to ignore the body. Stimuli were presented for 600ms in Experiment 1 ($n = 24$) and for an unlimited time in Experiment 2 ($n = 17$ to date). Accuracy, response times, and proportion of errors were analyzed. In Experiment 1, congruency effects were pervasive but strongest when sad faces were presented on fear bodies ($p < .01$) , followed by when fear faces were presented on sad bodies ($p < .05$). Congruency effects were dampened in Experiment 2, but were still strongest when sad faces were paired with fear bodies ($p < .03$). Collectively, these results question the predictive validity of both models and suggest that fear postures may hold a special status in emotion perception.

Acknowledgement: SSHRC

53.314 Beyond Darwin: revealing culture-specificities in the temporal dynamics of 4D facial expressions.

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Since Darwin's seminal work on the evolutionary and biological origins of facial expressions, the Universality Hypothesis maintains that all humans express six basic emotions - "happy," "surprise," "fear," "disgust," "anger" and "sad" - using the same set of distinct facial movements. Testing this hypothesis directly, we used a novel platform to generate random 3-dimensional facial movements, which observers perceive as expressive when correlating with their mental representations. Fifteen Western Caucasian (WC) and 15 East Asian (EA) observers each categorized 4,800 (same and other race) animations according to the six basic emotions (or "don't know") and by intensity ("very low" to "very high." Figure S1, Panel A). We then reverse correlated the random facial movements with the emotion responses they elicited, thus computing 180 models per culture (15 observers x 6 emotions x 2 race of face). Each model comprised a 41-dimensional vector coding the facial muscle composition and temporal dynamics. The Universality Hypothesis predicts that these models will form six distinct clusters (one per emotion) in each culture and show similar signaling of emotional intensity across cultures. We show cultural divergence on both counts: Cluster

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analysis of the models in each culture revealed that WC models optimally form 6 distinct and emotionally homogenous clusters as predicted (Levenson 2011), whereas EA models overlap between emotion categories, with little categorical structure (Figure S1, Panels B-C). Cross-cultural comparison of emotional intensity signaling across time (i.e., co-variation of facial movements and intensity) revealed further cultural differences. Whereas WC models signal emotional intensity with distributed face regions, EA models showed early signaling with the eyes, as mirrored by popular culture EA emoticons -- (^.^) "happy" and (O.O) "surprise." Here, we refute the Universality Hypothesis and raise the question: if the 6 basic emotions are not universal, which emotions are basic in different cultures?

Acknowledgement: Economic and Social Research Council

53.315 Categorical structure and perception of facial expressions in dyadic same-different task

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Emotional facial expressions are perceived categorically by individual subjects in discrimination and identification tasks (Young et al., 1997). We tested whether this effect can be replicated in shared same-different task. Participants, arranged in 15 dyads, were synchronously presented pairs of images for 3 s on two separate displays. The task was to discuss the images and decide, whether they were same or different, without seeing each other's image. As stimuli, we used 6 stills from video record of male poser performing transition between happy and surprised facial expressions. To explore the strategies used and structure of verbal categories, participants' eye movements and speech were recorded. Overall task performance analysis showed categorical perception (better discrimination of images far from categories prototypes) in 1-step pairs, and U-shape function in pairs of identical images. Although free description was allowed, the verbal units used fall into three main categories: configural (describing facial features deformation), emotional and situational. Based on their performance, dyads of participants were divided into 3 equal groups. Comparison of verbal activity in contrast groups showed: in the low performance group (0.62–0.7), the mean amount of verbal units per trial was distributed equally across all stimuli pairs; in the high performance group (0.82–0.94), it increased significantly while discussing same images or 1-step pairs, and the use of emotion terms was more diverse (low group subjects preferred more general descriptors like "happy" and "surprised" without mentioning complex mixed emotions). Low performance dyads showed no clear categorical perception. Moreover, the average eye fixation patterns differed significantly: dyads with lower performance observed the eyes area longer, and subjects with higher performance paid more attention to the mouth region. We suggest that, on happy-sad transition, extended verbal description and relying on mouth transformation help to elaborate more effective strategies in dyadic images differentiation.

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53.316 Face space is not linear: Empirical evidence of curvature and compression

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Face perception studies and models often assume that face space is linear, that is, that changes in gender or emotion produces linear changes in facial features. In the current study, we test the linear face space assumption by measuring additivity (i.e. whether the combination of gender and emotion is predicted by the sum of its components), proportionality (i.e. whether the ratio of internal-to-physical changes is constant, or whether there are compression or expansion effects at higher gender or emotion intensities), and directionality (i.e. whether increasing gender or emotion intensity introduces qualitative changes). Participants were told to produce faces that corresponded to various intensities along male/female and happy/sad continuums, including combinations of the two dimensions. They produced these faces using Poirier and Faubert (VSS 2010; in revision)'s technique, using sliders to adjust 53 components of facial expression including the shape and position of eyes, eyebrows, mouth, nose, and head. Data from 7 participants show that (1) variability along gender and emotion was captured by 3 dimensions: gender, emotion, and curvature (see below), accounting for 70.7% of variability in features ($F(61, 500)=1.8$, $p=.0002$), (2) gender and emotion were linearly additive within the range tested ($F(12,560)=1.2$, $p=.30$), (3) there was evidence of compression at high intensities for both gender ($F(5, 30)=3.6$, $p=.012$) and emotion ($F(5,30)=5.0$, $p=0.002$), (4) maximum expansion occurs at 0.5x female and 0.5x happy, and (5) the face space is significantly curved along both gender and emotion (R2s=49.1% & 57.4%, $Fs(1,10)=9.7$ & 13.5, ps=.011 & .0043 respectively) meaning that intensity changes introduced qualitative changes that cannot be captured as linear feature changes. The presence of deviations from linearity (e.g. compression, expansion, and curvature) implies that linear morphs as commonly used in experiments and virtual reality introduce both quantitative and qualitative systematic distortions, at least for variations involving gender and/or happy/sad.

Acknowledgement: NSERC-Essilor grant and an industrial research chair and an NSERC discovery fund awarded to Jocelyn Faubert

Face perception: Experience and learning

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

53.317 Implicit learning of geometric eigenfaces: evidence for the formation of face space dimensions

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The face space hypothesis suggests that individual faces are encoded as points in a multidimensional space, whose dimensions are formed based on experience with faces (Valentine, 1991). Approaches based on Principal Component Analysis (PCA) have been widely used to extract dimensional information from faces in developing automated face recognition algorithms (Turk & Pentland, 1991) and in recent investigation of the psychological properties of the face space dimensions (Said & Todorov, 2011). However, there has not been any evidence showing that humans learn dimensional information from experience with faces in a way similar to PCA. In the current study, we set up a multidimensional stimulus space with synthetic faces that capture the major shape information in real faces. Adult participants (N = 10) studied a set of 16 synthetic faces sampled from this multidimensional stimulus space, and subsequently performed an old/new face recognition task with the distracter faces being 16 faces from an non-overlapping region of this stimulus space relative to the 16 studied faces. In addition, participants also judged 3 faces representing the average and two directions of the first principal component (the eigenfaces) of the studied faces. Participants learned the target faces well, as demonstrated by a high hit rate (.74) and a low false alarm rate (.12). However, they mistakenly reported that they had previously seen the average face and the eigenfaces of the studied faces and did so at a rate (.98, .95, .97 for the average face and two eigenfaces, respectively) even higher than their rate of correct reports for the learned faces (ps <.01). The findings suggest that human adults implicitly learn the average and several principal components from experience with faces, offering direct evidence for the formation of face space dimensions.

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53.318 Practice with inverted faces selectively increases the use of horizontal information

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Perceptual learning improves face recognition, and learning is highly specific and long-lasting (Hussain et al., Psych Sci 2011). Even inverted faces can benefit from learning (Hussain et al., Vis Res 2009). But what changes in our representations of faces with learning? Last year, we demonstrated that the preferential use of horizontal information ("horizontal tuning") is correlated with upright face identification accuracy and the size of the face inversion effect (Pachai et al., VSS 2011). In the current study, we asked whether perceptual learning for faces is associated with an increase in horizontal tuning. Specifically, we tested inverted faces in a 10AFC identification paradigm where stimuli were the average of 10 faces viewed through different filters. Information from the target face alone was visible only within orientation bandwidths ranging from 10 degrees to 180 degrees (full-face) in 10 degree steps, centred around horizontal or vertical. In the first session, observers completed 10 trials in each condition to measure initial horizontal tuning. In the following three sessions, observers completed 300 trials/session of full-face identification. The fifth session was identical to the first. Observers returned 3-5 days later to assess maintenance of learning and transfer of learning to a new face set. As expected, training significantly improved inverted full-face identification. Critically, training also improved accuracy for faces with narrow-band filters centred on horizontal, but not vertical, suggesting an increase in horizontal tuning. Tuning was maintained in the follow-up session, but did not transfer to novel faces. These results suggest that perceptual learning improves horizontal tuning for trained face stimuli while improving overall identification accuracy, further implicating the importance of horizontal information for accurate face identification regardless of picture-plane orientation, and suggesting that the relatively high efficiency of processing horizontal information for upright faces may be a result of learning across the lifespan.

Acknowledgement: Canada Research Chair programme and NSERC

53.319 **Effects of spatial caricaturing and anti-caricaturing on face learning**

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Distinctiveness as a crucial parameter in face learning can be experimentally manipulated by spatial caricaturing. Building on recent findings of a learning advantage for spatially caricatured faces (Kaufmann & Schweinberger, 2008, in press), we investigated effects of spatial caricaturing as well as anti-caricaturing on face learning. We assessed performance and event-related potential (ERP) correlates of learning and recognition for 120 unfamiliar faces that were either presented as veridicals, caricatures, or anti-caricatures, using different images at learning and test, plus an equal number of novel faces from each of the three conditions. (Anti-) caricatures were manipulations of individual shape information, which was either exaggerated or reduced at 70% relative to a gender-matched averaged face, while preserving texture and color information. In a following two-alternative-forced-choice face familiarity-task, recognition accuracies were highest for caricatures, while response times were longest for anti-caricatures. At learning, caricatures elicited more negative occipitotemporal P200 and N250 than veridicals and anti-caricatures, which differed from one another at right hemispheric sites only. Right-hemispheric N170 and overall late positive component (LPC) were also larger for caricatures compared to veridicals and anti-caricatures. At test, P200, right-hemispheric N250 for learned faces, and LPC showed opposite amplitude effects for caricatures and anti-caricatures, with intermediate amplitudes for veridical faces. Altogether, the effects corroborate an interpretation of spatial caricaturing effects in terms of increased distinctiveness of facial shape. Spatial caricaturing affected face learning and recognition from early time windows onwards, with some evidence of higher sensitivity of the right hemisphere for facial shape. Effects were not only caused by spatial manipulations per se, but were in line with the direction of the distinctiveness manipulation.

53.320 **Behavioral and Neural Markers of Perceptual Expertise with Faces and Chess**

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Object recognition depends both on the recognition of parts of an object (featural processing) and how those parts interact (configural or holistic processing). Face recognition appears to disproportionately rely on holistic processing, as revealed by behavioral hallmarks such as the increased performance cost of face inversion relative to other objects. While evidence suggests a genetic role in face recognition, the effects of experience must be understood in order to devise training methods for those impaired in face recognition. Here, we summarize our present research in this area by presenting behavioral and neuroimaging results with experts with another visual stimulus, chess. Chess position recognition bears some similarities with face recognition, in that both parts (individual pieces) and relationships among pieces must be recognized to evaluate a position. However, unlike face recognition, chess expertise does not appear to be genetic. We tested chess experts, recreational players and novices behaviorally with interleaved face and chess composites to see whether chess experts demonstrate hallmarks of face processing with chess stimuli. All participants demonstrated one hallmark of holistic face processing, congruency, with face composites, but only chess experts demonstrated a congruency effect with chess composites. Chess experts also processed faces differently—less holistically—than novices, suggesting interference from the chess stimuli, and this pattern was associated with an early starting age with chess. Given that the behavioral results with chess experts suggested that expert chess processing and face processing may share a common process, we used functional Magnetic Resonance Imaging (fMRI) to identify the neuro-correlates of meaningful chess stimuli among experts and novices in a recognition task. Results suggest that recognition for faces and chess have separate neural correlates; the Fusiform Face Area was not associated with expert processing of normal versus randomized games. Other areas, such as the precuneus, were associated with well-formed games.

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53.321 **Spatial and temporal characteristics of the neural representation of face familiarity**

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Familiarity increases our ability to recognize faces in challenging viewing conditions. We investigated how brain response patterns change as unfamiliar faces become visually familiar. A pattern-based classifier was applied to discriminate the spatial and temporal characteristics of brain responses in areas implicated in familiarity and face processing (FFA, OFA, fusiform gyrus, lateral-occipital areas, and parietal areas including the precuneus). First, in a behavioral study, we developed a learning paradigm for achieving high, medium, and low levels of familiarity by varying the number of learning exposures to multiple views of a face. Recognition of the learned faces from whole-body images increased as a function of familiarization level. Next, in an fMRI experiment, a second set of participants learned faces in the high, medium, and low familiarization conditions before the scan. Neural data were recorded while participants viewed blocks of high, medium, and low familiarized faces, as well as unfamiliar faces. The pattern classifier was used to discriminate the neural activity elicited in response to viewing faces from all pairs of familiarity conditions (e.g., high vs. medium). The most accurate discrimination was found using the combination of the fusiform gyrus, lateral-occipital areas, and parietal areas, suggesting coordination of these areas in the neural coding of face familiarity. Moreover, in the FFA-OFA, discrimination scores increased as a function of increasing levels of familiarity. A pattern classification analysis applied across the temporal sequence of the block showed that the pattern of FFA-OFA response differed with familiarity. Highly familiar faces were classified from unfamiliar faces earlier in block than medium and low familiarity faces. Finally, we confirmed the lack of neural magnitude differences in FFA-OFA as a function of familiarity. This suggests that the acquisition of familiarity is characterized by differences in spatial and temporal patterns of neural activation across a network of brain areas.

53.322 **Unconscious use of the body in identifying the face**

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The human face usually provides reliable information for determining a person's unique identity. We tested identification when faces provided misleading information about identity due to illumination and expression variability. "Misleading" information was defined based on the performance of a fusion of face recognition algorithms from a recent international competition. Two kinds of stimulus pairs were selected: highly similar images of different people and highly dissimilar images of the same person. In four experiments, humans judged whether the pairs (n = 100) showed the "same person" or "different people". Three versions of the image pairs were tested. In Experiment 1, participants saw the original images, which included the face, neck, and shoulders of each person. In Experiment 2, the original image was cropped to include only the face. In Experiment 3, the original image was edited to remove the face, leaving the hair, neck, and shoulders. Participants matched identity accurately in the original images ($d' = 1.5$, se = 0.15), but performed at chance with the face alone ($d' = 0.36$, se = 0.15). Performance with the neck and shoulders was virtually identical to performance with the complete images ($d' = 1.5$, se = 0.09). This indicates that use of the body information accounts for the accurate matching of the original complete images. An item analysis revealed that identification without the face was more accurate than identification with the complete image for 50 percent of the stimuli, indicating that the presence of a face can actually interfere with the use of the body for identification in suboptimal viewing conditions. Experiment 4 replicated Experiment 1, but with par-

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ticipants asked to rate their use of 16 internal (e.g., eye shape) and external (e.g., neck) features. People uniformly reported greater reliance on internal over external features, suggesting limited conscious access to their identification strategy.

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53.323 Title: Familiarity and the Recognition of Disguised Faces

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People have the ability to transform the appearance of the facial region with the application of make-up, growing or shaving of facial hair, addition or removal of glasses, alteration of hair style or color, and race of the individual. All of these transformations have an impact on the ability to recognize a person, though it's unclear how much of an impact, and the degree to which different transformations disrupt recognition. The purpose of this study was to add to existing knowledge about the ability of human subjects to recognize naturalistic faces in disguise. We investigated the effects of different types of changes that altered the appearance of the faces from presentation to test (e.g., addition or subtraction of eyeglasses, or a wig). Also included are the levels of familiarity on recognition between races. People were familiarized with faces three, six, or nine times while performing judgment tasks (e.g., attractive vs. unattractive) with individuals either in disguise (wig and/or glasses), or no disguise. During the testing phase, participants were shown previously learned and novel individuals, both with and without disguise. Participants were familiarized with a 45-degree rotation and tested with frontal views. Also tested was race to see how familiar participants were with other race faces. Results indicated that any change from presentation to test lowered accuracy, and as the number of changes increased, performance decreased. Eyeglasses hindered recognition, but results indicated little difference between tinted and clear-lens glasses in their effect on performance. The participant's scores for addition vs. subtraction of eyeglasses replicated prior work showing that encoding a face with eyeglasses and removing them before the recognition task was more damaging than an addition. Although no significant main effect was found for familiarity, post hoc tests did indicate a significant difference between familiarizing someone three times versus nine times.

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53.324 Movement helps famous and unfamiliar face matching: Evidence from a sorting task

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We can use the characteristic way a person moves their face and head ("dynamic facial signatures") as a cue to identity. Theoretically, we should have pre-existing representations of the way a familiar face moves, making it easier to match the movement of familiar than unfamiliar faces. However, few studies have directly compared the benefits of movement for familiar and unfamiliar faces. It is also unclear whether the use of dynamic facial signatures depends on the type of movement, or a particular face area. In this study, we investigated the movement advantage for famous and unfamiliar faces using a sorting task. Participants sorted groups of moving or static shape-normalized point-light-displays (PLDs), using either rigid head movement (e.g. nodding, tilting), non-rigid face movement (e.g. smiling, talking) or combined rigid and non-rigid movement. In Experiment 1, standard PLDs were used. In Experiment 2, the PLDs included eyes, while in Experiment 3, they included the teeth and tongue. Accuracy scores were divided by the average number of times clips were viewed. Famous and unfamiliar faces were sorted equally well overall. Famous faces showed a movement advantage for combined and non-rigid clips, but not rigid clips. The results suggest that participants were using mouth information: famous face PLDs with mouths were sorted better than standard PLDs or PLDs with eyes. Like famous faces, unfamiliar faces also showed a movement advantage for combined motion. Unlike famous faces, unfamiliar faces were sorted equally well from standard PLDs and those with mouths or eyes. Overall, these results show that both famous and unfamiliar faces can be sorted based on dynamic facial signatures. Sorting famous faces may rely more on non-rigid movements of the mouth region than on the eyes or rigid motion, whereas sorting unfamiliar faces is best when both rigid and non-rigid movement are present.

53.325 Serial Dependence of Face Identity

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How do we achieve stable and continuous perception of the objects around us despite ever-changing visual input? One mechanism for stability may be serial dependence in visual perception. We have previously shown (Fischer, Shankey, & Whitney, VSS, 2011) that the perception of basic features (e.g., orientation) depends not only on current visual input, but also on prior input extending back 10 or more seconds. Serial dependence is a potential mechanism for stable object perception, but a key unanswered question is whether it operates beyond the level of basic features. Here, we used face stimuli to test for serial dependence at the level of holistic object information. In these experiments, faces were drawn from a continuous morph of facial identities and subjects were asked to report their perception of identity in (1) an adjustment task and (2) a two-interval forced choice task (2IFC). In the adjustment task, subjects adjusted the identity of a test face to match the identity of a target face they had just seen. Subjects made consistent perceptual errors when reporting the perceived identity of the target face on the current trial, seeing it as more similar to the identity presented on the previous trial. In the 2IFC task, the target face for each trial was drawn from a subset of morphs between identity A and identity B, and subjects determined if the target face or a subsequently presented probe face was more A-like. Subjects were more likely to report the target face to be more A-like if the target on the previous trial was relatively more A-like, and vice versa. Using two different tasks, we have converging evidence that current perceived identity is attracted to previously encountered identities. Therefore, serial dependence does occur at the object level, contributing to our stable representation of objects.

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53.326 Efficiency of face recognition depends critically on size

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In an earlier work we hypothesized that face recognition processing may undergo a qualitative shift at around a critical size of 4-5 degrees, with expert face processing dominating recognition at larger sizes. This was based on our results showing that critical spatial frequencies used for face recognition increase with size for faces smaller than 4.7 degrees but stabilize at a lower relative frequency for larger faces (Oruc & Barton, 2011). In this study we explicitly tested this hypothesis by measuring contrast thresholds for recognizing upright and inverted faces at sizes between one and ten degrees of visual angles. We computed recognition efficiencies by comparing human data to the performance of an ideal observer on the same task. Our modified "CSF-ideal" observer model is limited by the same visual acuity and sensitivity constraints as our human observers, rendering the performance of the CSF-ideal observer dependent on stimulus size (Oruc & Landy, 2009). Thus our CSF-ideal incorporates any decreases in recognition performance that are solely due to visibility constraints of the human observers introduced by size. The pattern of upright face recognition efficiencies showed a step-function-like profile with efficiencies doubling abruptly at 5 degrees per face width. On the other hand, efficiencies for inverted faces remained largely flat across the size range tested. The critical size at which the shift for upright faces occurs corresponds to viewing a face at around one and a half meters in the naturalistic setting. These results show that face size is a critical factor in recognition performance. Although not conclusive, they also suggest that in upright-face perception distinct recognition processes are involved depending on size, with expert processes dominating sizes typical of close-range social interaction.

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53.327 The 'other-species effect' in chimpanzees but not rhesus monkeys

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Face space is a powerful theoretical framework for understanding the representation of face identity in humans. It has been used to explain several face specific phenomena including the inversion and other-race effects (ORE). The ORE refers to the finding that we are better at discriminating faces of our own compared to other races. Face space predicts that other-race faces will be densely clustered and distinctive, reflecting their unique, poorly discriminated features. For nonhuman primates, the analog of the ORE is the other-species effect (OSE), the finding that conspecifics' faces are discriminated better than heterospecific faces. The extent to which the OSE is present in nonhuman primates is unclear. Recent studies have suggested that rhesus monkeys may be face-generalists, processing all faces in a similar manner, while the conspecific face has acquired a special status for chimpanzees. The present study utilized a face space framework to directly compare the OSE in nonhuman primates. Rhesus monkeys and chimpanzees were required to discriminate between conspecific and heterospecific faces using a computerized matching-to-sample task. Ninety unique combinations of 10 individuals were presented, including both chimpanzee and rhesus monkey faces representing the conspecific and heterospecific stimuli for each subject species. Subjects' performance was analyzed using multidimensional scaling and the mean interstimulus distance for each face was calculated. Similar to the ORE in humans, chimpanzees showed significantly better performance discriminating conspecific vs heterospecific faces, and the mean interstimulus distance was smaller for heterospecific vs conspecific faces. Rhesus monkeys showed no significant difference in performance or interstimulus distance between conspecific vs heterospecific faces. Therefore, these data confirm that the conspecific face has acquired a special status for chimpanzees, but not rhesus monkeys. These results suggest that for both chimpanzees and humans, the face processing system becomes specially tuned for the most frequently encountered faces.

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53.328 Evidence for an own-age-bias to face stimuli in the distributed responses of fusiform gyrus

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Recent studies suggest that face selective regions in the fusiform gyrus undergo a prolonged development involving substantial increases in their spatial extent after age 7 years. It is unknown if this development is sensitive to recent visual experience with own-age faces or cumulative experience with faces of any age. Thus,we examined the development of responses to own- vs. other-age faces in the ventral temporal cortex of children (7 – 11 year olds, n = 10), adolescents (12 – 16 year olds, n = 11) and adults (18 – 40 year olds, n =12). Images of child and adult faces, objects and places were presented in pseudo-randomly ordered blocks in 2 runs, during functional magnetic resonance imaging (fMRI) in a 3T scanner. Subjects fixated and performed a 1-back task. We drew the anatomical boundaries of the fusiform (FUS) and parahippocampal (PHG) gyri and defined face-selective regions (adult & child faces > objects, p <10-3) on each subject's gray matter. We found that regardless of the age of face stimuli the volume of the face-selective regions in FUS were substantially larger in adults than in children or teens. Importantly, distributed responses in the FUS, outside face-selective regions showed significantly higher correlations (between runs 1 and 2) and higher classification accuracy for adult faces than for child faces, in adults only. Meanwhile, correlation and classification accuracy for child faces were similar among children and adults. These effects were regionally specific, as there were no age effects in distributed responses of the PHG or of face selective regions in FUS. Together, these results suggest an interaction between age-of-subject and age-of-face stimuli among the weakly face-selective voxels of FUS, consistent with a prolonged development of face selectivity during childhood and adolescence that may depend on the exposure and social relevance of various types of faces.

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53.329 Adults Scan Own- and Other-Race Faces Differently

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It is well established that individuals show an other-race effect (ORE) in face recognition: they recognize own-race faces better than other-race faces. The present study tested the hypothesis that individuals would also scan own- and other-race faces differently. We asked Chinese participants to remember Chinese and Caucasian faces and we tested their memory of the faces over five testing blocks. The participants' eye movements were recorded with the use of an eye tracker. The data were analyzed with the use of the Area of Interest approach with the key AOIs of a face (eyes, nose, and mouth). Also, we used the iMap toolbox to analyze the raw data of participants' fixation on each pixel of the entire face. Results from both types of analyses strongly supported the hypothesis. When viewing target Chinese or Caucasian faces, Chinese participants spent a significantly greater proportion of fixation time on the eyes of other-race Caucasian faces than the eyes of own-race Chinese faces. In contrast, they spent a significantly greater proportion of fixation time on the nose and mouth of Chinese faces than the nose and mouth of Caucasian faces. This pattern of differential fixation, for own- and other-race eyes and nose in particular, was consistent even as participants became increasingly familiar with the target faces of both races. The results could not be explained by the perceptual salience of the Chinese nose or Caucasian eyes because both the Chinese and Caucasian eyes were equally salient and their noses were equally not salient. Our results are discussed in terms of the facial morphological differences between Chinese and Caucasian faces and the enculturation of mutual gaze norms in East Asian cultures.

Acknowledgement: NIH

53.330 A test of the perceptual expertise hypothesis with novel race faces

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Although a large body of evidence in the face recognition literature indicates that we are better at recognizing faces from our own race than faces from other races (i.e., the Other-Race Effect or ORE), the precise mechanisms mediating the ORE are not well understood. It has been speculated that people encode in-group, own-race faces as individuals and classify out-group, other-race faces in terms of race. According to the perceptual expertise hypothesis, the more specific, subordinate level of recognition of own-race faces demands a finer grain of perceptual analysis. It has been suggested that this type of expert perceptual analysis is selectively tuned to the recognition of within-race faces, but does not apply to the recognition of between-race faces. ORE research is complicated by the fact that participants differ in the degree and kind of own- and other-race familiarity. In the current study, we addressed the familiarity issue by creating two novel races, the Thutmosians and the Guansians. Members of the Thutmosian race differed in the upper eye region of the face where members of the Guanshian race varied in the lower mouth region. As a direct test of the perceptual expertise hypothesis, participants were trained to either individuate Thutmosian faces and categorize Guanshian faces or vice versa. Recognition performance was assessed with a new set of Thutmosian and Guanshian faces in an old/new recognition test administered before and after training. The main finding was that individuation training produced reliable gains in recognition of faces from the individuated race whereas categorization training had little effect on the recognition of faces from the categorized race. Consistent with the perceptual expertise hypothesis, our results suggest that it is the kind, not the amount of racial experience that determines the ORE.

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53.331 Race differences in eye movements to three-quarter view faces

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A number of studies have shown a difference between Asian and Caucasian participants in fixation patterns to faces. Caucasian participants' fixations are concentrated on the eyes, whereas Asian participants fixate more centrally on the nose region. All previous studies exploring race differences have used front view faces. The present study investigated whether this preference for fixating the nose in Asian participants extends to three-quarter (mid-profile) view faces. Eye movements were monitored during the learning and recognition phases of a memory task for three-quarter view Asian and Caucasian faces. We found Hong Kong Chinese participants predominantly fixated both the nose and central-eye (eye closest to the observer) regions of the three-quarter view faces at both study and test. There was no difference in the proportion of fixations to the nose and the central eye, and we found that Asian and Caucasian faces elicited similar fixation patterns. These results differ from previous findings for front view faces where Asian participants showed a significantly greater proportion of fixations towards the nose than the eyes. The results also differ from recent findings for three-quarter view faces in Caucasian participants where the central eye received a far higher proportion of fixations than the nose. These results suggest that race influences fixation patterns to non-frontal views of faces.

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53.332 **Developmental prosopagnosia in children: A case study of improvement in face recognition as a result of training**

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Developmental prosopagnosia (DP) refers to an inability to recognize faces despite no brain injury and often typical IQ, emotion recognition, and object recognition. Little is known about this disorder in children and few studies have examined training programs for DP children. We present a case study of a child with DP, referred to as B, who completed a training program, FaceSay (Symbionica, LLC). Participant: B is a healthy male of above-average intelligence with no neurological disorder, behavioral disorder, or other visual impairment. Methods: We measured B's facial recognition skills four times over 21 months using the Cambridge Face Memory Test for Children. He then completed eight weeks of training using the FaceSay Program for 25 minutes, 2 times a week. B was trained to recognize emotions and faces and follow gaze. Two post tests followed training. Results: Before training, B performed at chance on all pre-tests (50.0% 48.3%, 46.7%, 58.3%; 50% is chance); average performance of typically developing 7- and 8-year-old children on this test is 75% and 80% respectively (sd = 10.8 and 10.7, n = 84 and 43). After training, B answered correctly on 74% of trials both immediately post-training and 1 month post-training. Discussion: Given that B showed no improvement across 4 baseline assessments and no improvement between the two post-test assessments, it is unlikely that experience with the test improves performance. This is one of few studies of a training program done with children with DP. While B improved performance on the CFMT, it is yet unclear why training was successful or if the improvement generalizes to face recognition skills outside the laboratory. Although it should be kept in mind that this is only a case study, these results suggest that it may be possible to improve face recognition abilities in children with DP.

Eye movements: Pursuit and following

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

53.401 **Localization of visual targets during open-loop smooth pursuit**

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Numerous studies in recent years have shown that eye movements induce errors in the localization of briefly flashed stimuli. Smooth pursuit and the slow phases of optokinetic nystagmus (OKN) and optokinetic afternystagmus (OKAN) are different forms of so-called slow eye-movements. Pursuit is induced by the movement of a small target whereas large field motion induces a reflexive alternation of slow- and fast phases, the so-called OKN. Finally, OKAN is observed in total darkness after prolonged OKN. Accordingly, OKAN is considered an open-loop eye movement. During pursuit and OKN, perceived flash positions are shifted in the direction of the slow eye movement. During OKAN, however, localization has a foveofugal bias. Here, we examined flash localization during open-loop pursuit and asked, whether localization is prone to errors and whether this error is similar to the one found during visually guided smooth pursuit or during OKAN. Human subjects tracked a pursuit target. In half of the trials, the target was extinguished for 300 ms during the steady-state, inducing open-loop pursuit. Flashes were presented during this gap (gap condition) or during steady-state pursuit (control condition). In both conditions, perceived flash locations were shifted in the direction of the eye movement. While error patterns were similar in both conditions, shifts were slightly, yet significantly, smaller in the gap condition. During steady-state and gap-pursuit, localization error did not correlate with eye velocity. Precision of localization changed for stimuli presented during the gap. Compared to steady-state, it decreased ahead of target and increased in its wake. This concurs with a widening of the attentional spotlight during gap-pursuit. Considering that mislocalization was not correlated with eye velocity and that the mislocalization pattern during open-loop pursuit was steady-state pursuit-like rather than OKAN-like, we suggest that an internal representation of the pursuit target contributes to mislocalization during open-loop pursuit.

Acknowledgement: Supported by DFG FOR-560

53.402 **Dynamics of oculomotor direction discrimination**

Doris Braun[1](doris.braun@psychol.uni-giessen.de), Karl Gegenfurtner[1]; [1]Giessen University

Primates use smooth pursuit and saccadic eye movements to track moving objects. Continuous foveation requires good estimates of target speed and direction. When position and velocity errors get too large, catch-up saccades are triggered. The pursuit system typically reaches an asymptotic direction precision similar to that for perception. We explored the dynamics of directional precision during pursuit initiation and initial saccades. We used a step ramp paradigm to obtain pure pursuit initiation, and a ramp paradigm to elicit an initial saccade followed by pursuit. Small Gaussian blobs moved horizontally across a CRT screen at 10 deg/s in 7 different directions between +/- 10 deg. Instantaneous direction of eye motion at different points in time after pursuit onset were compared to the eye direction obtained for a purely horizontal stimulus. This way, oculometric functions were constructed for direction at each point in time, indicating how well the oculomotor system can discriminate direction. The same calculations were performed for the ramp paradigm, where we also calculated oculomotor direction performance based on the endpoint of the initial saccades. In the step-ramp paradigm, it took about 400 ms after stimulus motion onset for pursuit to reach its minimum threshold of about 2 deg. In the ramp paradigm, initial saccades occurred at 190 ms on average. The saccadic endpoint indicated stimulus direction with a precision of 3.3 deg. At this time, about 100 ms after pursuit onset, pursuit oculometric thresholds for the step-ramp paradigm were still larger than 20 deg and took at least 100 ms longer to reach this value. We conclude that the saccade system reaches more precise estimates of target direction, presumably through the use of positional information that is not available for the pursuit system. Post-saccadic enhancement of eye movement precision might be caused by this saccade-pursuit synergy.

53.403 **Continuous updating of superior colliculus visuospatial memory responses during smooth pursuit eye movements.**

Suryadeep Dash[1](suryadeep.dash@gmail.com), Xiaogang Yan[1], Hongying Wang[1], J. Douglas Crawford[1,2,3]; [1]Center for Vision Research, York University, Toronto, Canada, [2]Departments of Psychology, Biology, Kinesiology & Health Sciences, York University, [3]Canadian Action and Perception Network (CAPnet)

Spatial updating is a process that enables us to constantly compute spatial relationships between ourselves and the surrounding environment during self-motion. Primates are able to spatially update saccade targets across intervening saccade or smooth pursuit (SP) eye movements. Various studies have demonstrated discrete remapping of visual responses, in several brain structures, before and after the saccade. However, no study to date has shown continuous updating of such responses during the eye movement, nor has anyone published a study of the neural mechanism of spatial updating for SP. In this study we recorded superior-colliculus unit activity from 2 monkeys. Animals were trained to spatially update the location of a saccade target across an intervening SP. Neurons were characterized (as visual, visuo-motor or motor neurons) and their visual / motor receptive fields (RF) were specified using a delayed saccade paradigm. After this each neuron was tested in the SP-saccade paradigm. Saccade target direction and pursuit ramp length were varied such that (across trials) the remembered saccade target passed approximately through the neuron's RF at 2-5 different points on the SP ramp. Of the 50 neurons analyzed to date, every neuron that showed a visual response (n=47), whether it was a visual and visuomotor neuron, exhibited a clear and robust modulation in activity when the location of remembered target passed across the RF of the neuron during SP. In contrast, none of the motor neurons showed any updating related response, but instead only burst for an intended saccade. We conclude that 1) the superior colliculus visual memory response is continuously updated during SP eye movements in a gaze-centered coordinates, and 2) only visual responses (not motor) are involved in visuospatial memory. This may reflect a general mechanism for continuous updating during slow self-motion.

Acknowledgement: Supported by CIHR, CRC (Crawford) and MRI (Dash)

53.404 **Relative contributions of stimulus motion and VOR to eye movement during gaze pursuit**

Jared Frey[1](jrfrey@ucla.edu), Abtine Tavassoli[2], Dario Ringach[1,2,3]; [1]Biomedical Engineering IDP, Henry Samueli School of Engineering and Applied Sciences, [2]Department of Neurobiology, David Geffen School of Medicine, [3]Department of Psychology, UCLA

In the lab, smooth pursuit and the vestibulo-ocular reflex (VOR) are often studied in isolation, whereas in nature, they work simultaneously. To see how these systems operate in conjunction, we sought to decompose the eye velocity signal during head-free gaze pursuit two components: one attributable to stimulus motion and another due to head movement. To accomplish this, human subjects tracked a target dot moving at constant velocity plus a noisy perturbation term across large excursions (67 deg). Subjects were free to move their heads and both head and eye movements were recorded. Using regression, we recovered linear filters describing the relative contributions of stimulus movement and head movement to the eye movement. We could account for over 50% of the variance of the eye movements from these two components. The stimulus component was similar to previously reported filters derived from head-fixed smooth pursuit maintenance(Tavassoli and Ringach, 2009). The head movement component is consistent with a partially unsuppressed VOR. We found no evidence for any further coordination mechanism or shared noise source as the cross-covariance between head and eye velocities could be explained by the partially unsuppressed VOR. In conclusion, we were able to separate linear components of the smooth pursuit and VOR without external perturbations of the head during gaze pursuit maintenance which could account for a significant portion of eye movement variability. Tavassoli, A. and D. L. Ringach (2009). "Dynamics of smooth pursuit maintenance." J Neurophysiol 102(1): 110-118.

53.405 **The oculomotor system can discriminate perceptually suppressed motion: an oculometric analysis**

Davis M. Glasser[1,2](dglasser@cvs.rochester.edu), Duje Tadin[1,2,3]; [1]Center for Visual Science, University of Rochester , [2]Department of Brain and Cognitive Sciences, University of Rochester, [3]Department of Opthalmology, University of Rochester

The ocular following response (OFR) is a reflexive eye movement that occurs in response to large, high-contrast, and rapidly moving stimuli with an abrupt onset (Miles, Kawano, & Optican, 1986). It is believed to support the stabilization of the retinal image, especially after saccades. The stimulus conditions that optimally evoke the OFR are also favorable for eliciting behavioral spatial suppression (Tadin, Lappin, Gilroy, & Blake, 2003). That is, increasing the size of a high-contrast moving stimulus makes its motion harder to discriminate – but these same manipulations should also increase the magnitude and directional selectivity of the OFR. This disconnect between perceptual and oculomotor size tuning led us to hypothesize that perceptually suppressed stimuli would nonetheless yield measurable OFRs. To investigate this relationship, we presented observers with brief (67 ms), large (radius = 8°), high-contrast, rapidly moving (TF=16Hz) grating stimuli. We measured observers' psychophysical judgments of stimulus motion direction while simultaneously recording reflexive eye movements evoked by the same stimuli. As expected from our previous work, observers were unable to discriminate the direction of stimulus motion at above chance levels. However, these stimuli induced reliable OFRs that matched previously reported latencies and amplitudes. Specifically, for perceptually at-chance moving stimuli, OFR deflections predicted stimulus direction at ~0.75 probability. In the second experiment, we used signal detection theory to directly compare occulomotor and perceptual sensitivity to these brief moving stimuli. We repeated the above-described measurements across a range of stimulus durations to directly compare psychometric and oculometric functions for the same stimuli. The results revealed that occulomotor threshold were consistently lower than perceptual thresholds. Overall, these findings suggest that the oculomotor system has access to perceptually suppressed motion information. Finally, this conclusion indicates that the neural mechanisms underlying behavioral spatial suppression lie either subsequent or in parallel to those underlying the OFR.

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53.406 **Attention modulates anticipatory eye movements**

Stephen Heinen[1](heinen@ski.org), Zhenlan Jin[1], Scott Watamaniuk[2]; [1]Smith Kettlewell Eye Research Institute, [2]Psychology Department, Wright State University

Previously, we provided the pursuit system with an alternative drive to a foveal target using a large random dot cinematogram (RDC) stimulus that stimulated peripheral retina (Heinen et al., 2011). This manipulation improved performance on a secondary perceptual task during pursuit. The improvement was thought to occur because the RDC released foveal attention for the task, additionally implying that pursuit of an RDC requires less attention than does pursuit of a foveal target. If so, the RDC might preferentially activate subcortical rather than cortical neural circuitry. Since there is evidence that the cortical supplementary eye fields (SEF) are involved in generating anticipatory eye velocity (Missal &Heinen, 2004), it is possible that the RDC would not activate this region, and therefore produce less anticipatory eye movements. In the current study, observers pursued either a single spot stimulus, or a stimulus composed of a spot embedded in a large RDC. The stimulus moved at 20 deg/sec in a predictable direction. We found that anticipatory eye velocity was more prevalent, and was consistently higher for the single spot than for the RDC. We then increased attention at the fovea by having observers detect the dimming of the foveal target during pursuit. In this condition, anticipatory eye velocity was increased over that which occurred for pursuit of the spot without the task. The results suggest that anticipatory pursuit is facilitated during pursuit of the spot because attention is directed towards it, and further imply that pursuit of a large object requires less attention than does pursuit of a foveal one.

Acknowledgement: Smith-Kettlwell Eye Research Institute

53.407 **Anticipatory smooth eye movements with passive and actively-controlled target motions**

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Anticipatory smooth eye movements (ASEM) are smooth eye movements in the direction of expected target motion that begin before the onset of target motion or before an expected change in the direction of motion. We investigated the role of different cues in eliciting ASEM, either when the target was viewed passively, or was moved actively.The target was a disc that traveled down an inverted Y-shaped tube. A cue to the horizontal motion path was provided by blocking one branch of the Y with a visible barrier. ASEM in the cued direction were prominent, even from the first trial. Inverting the tube so that the cognitive cue of implied gravity was removed did not diminish ASEM. A non-visual cue, alternating right and left paths, was less effective than the visual cue. The same patterns of ASEM appeared in individuals with Autism Spectrum Disorder.When the motion of the disc within the tube was controlled by the subject's arm movements (via a mouse), anticipatory movements of the arm occurred, either when the motion path was cued by the visible barrier or was chosen freely. The eye closely followed with little or no lag, but did not lead, the anticipatory arm movements. Pursuit lagged further behind the target when the identical patterns of disc motion produced by the arm were instead tracked passively, showing the contribution of anticipation to smooth pursuit during active tracking. These results show that ASEM can be generated by visual cues to the direction of target motion that are semantically consistent with the scene, or non-visual cues provided by active control of motion. These findings suggest that anticipatory smooth eye movements are valuable for reducing retinal velocity errors, either when viewing natural scenes or during tasks requiring the coordination of hand and eye.

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53.408 **Like a rolling stone: naturalistic kinematics influence tracking eye movements**

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Tuesday AM

Tracking eye movements not only require an estimate of target motion but also predictions regarding the trajectory. In the present contribution we propose that this visuo-motor transformation takes into account prior information about object kinematics in the real world. In particular, the force of gravity constrains round objects to roll on the ground with particular rotational and translational speeds. We asked observers to track two different kinds of rotating discs, each one having the same visual motion energy at any point in time. Objects rotated in a direction that was either congruent or incongruent with their linear trajectory on the ground. For instance, a disk moving to the right and rolling clockwise has congruent linear and rotational directions of motion, while a disk moving to the right and rolling counterclockwise has incongruent directions of motion. The incongruent object has a "backspin" and appears to slip (not to roll) on the surface. In support of our hypothesis, the initial phase of tracking eye movements was slightly faster in the congruent compared to the incongruent condition.

53.409 **Attention for saccades and foveal pursuit is shared**

Scott Watamaniuk[1](scott.watamaniuk@wright.edu), Zhenlan Jin[2], Stephen Heinen[2]; [1]Department of Psychology, Wright State University, Dayton OH, [2]The Smith-Kettlewell Eye Research Institute, San Francisco CA

Performance on a secondary perceptual task improved when a large, random dot cinematogram (RDC) provided an alternative pursuit drive to a foveal target (Heinen et al., 2011). We hypothesized that the improvement occurred because the RDC released attention from the foveal target, implying that perception and pursuit share attentional resources. Physiological evidence demonstrates that mechanisms for the saccadic and pursuit systems overlap. Given this, we asked whether the saccadic and pursuit systems also share attentional resources. Observers pursued a small, foveal stimulus surrounded by four parafoveal target dots, and made a saccade to the target that was brightened and enlarged at a random time during the pursuit trial. The pursuit stimulus and parafoveal targets were presented alone or embedded in a large RDC moving at the same velocity. Saccade latency was shorter with the RDC present, suggesting that its benefit is not specific to the perceptual task in our earlier study. To test whether the RDC released foveal attention, we manipulated directly attention on the pursuit stimulus. Observers discriminated a brief color change applied to the pursuit stimulus 130 ms before the saccade target appeared, a time when attention to a briefly presented stimulus peaks (Nakayama & Mackeben, 1989). This eliminated the saccade latency reduction afforded by the RDC, presumably because the color change focused attention back on the fovea. However, if the color change occurred 350 ms before the saccade target appeared (when attention to a briefly presented stimulus subsides) latencies returned to the values seen with the RDC without the color change. The results suggest an RDC can release attention from foveal pursuit to facilitate saccade execution, evidence that attention for saccades and pursuit of foveal stimuli is shared.

53.410 **Pursuit eye movements and motion prediction in patients with schizophrenia**

Miriam Spering[1](mspering@mail.ubc.ca), Elisa C. Dias[2], Jamie L. Sanchez[2], Alexander C. Schütz[3], Daniel C. Javitt[2]; [1]Dept. of Ophthalmology & Visual Sciences, University of British Columbia, Canada, [2]Nathan Kline Institute for Psychiatric Research, Orangeburg, NY, [3]Dept. of Psychology, Justus-Liebig University Giessen, Germany

GOAL: Tracking moving objects with smooth pursuit eye movements is essential for many everyday tasks. These continuous, slow eye rotations critically support vision by centering and stabilizing moving images on the fovea; they prevent motion blur and enhance visual acuity. We recently discovered a strong perceptual benefit during pursuit eye movements in a trajectory prediction task [Spering et al., J. Neurophysiol., 2011]. Here we investigate the ability to predict motion trajectories in patients with schizophrenia. Previous studies with these patients have established pronounced motion perception deficits and abnormalities in pursuit, most notably, in the velocity gain. METHOD: Observers (11 patients, 12 age-matched controls) judged whether a linearly moving target ("ball") would hit/miss a stationary vertical line segment ("goal"). Ball and goal were shown briefly (200 or 500ms) on a computer monitor and disappeared before the perceptual judgment was prompted. We manipulated eye movements: observers had to track the ball with their eyes (50% trials) or fixate on the goal while the ball was moving towards fixation. RESULTS: We found similarities in pursuit eye movement accuracy (i.e., velocity gain, direction error) between patients and controls. Moreover, both groups equally showed more accurate pursuit in trials with longer presentation duration. In contrast, perceptual motion prediction performance differed between groups: Across conditions, motion prediction was overall significantly better in controls than in patients (75 vs. 68% correct). Motion prediction was also significantly better when stimuli were presented longer than when presented shorter – but only for controls (78 vs. 72% correct); patients showed no such effect of presentation duration. Together, these findings indicate that motion prediction deficits in schizophrenic patients are not mediated by pursuit eye movements alone, suggesting differential impairments in early visual processing for motion perception and pursuit.

Eye movements: Perception

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

53.413 **Feature-based effects in the coupling between attention and saccades**

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Previous research has demonstrated that prior to saccade execution visual attention is imperatively shifted towards the saccade target (e.g. Deubel & Schneider, 1996; Kowler, Anderson, Dosher, & Blaser, 1995). Typically, observers had to make a saccade according to an arrow cue and simultaneously perform a perceptual discrimination task either at the saccade target location or elsewhere on the screen. Discrimination performance was poor if the location of the saccade target and the discrimination target did not coincide. In the current experiments, we examined how feature-based attention may influence attentional allocation just before a saccade. In a first experiment, we randomly varied the colors of the saccade target and the perceptual discrimination target. Results show that discrimination performance was slightly, but not greatly improved when the color of the discrimination target matched the color of the saccade target. Thus, although perceptual performance at the saccade target location was facilitated, selection of an object as saccade target may not automatically induce display-wide enhanced processing of saccade target features or attentional capture by stimuli sharing saccade target features. We further examined whether feature-based attention may be strategically used to de-couple attention-for-perception and attention-for-action. We used a constant color to guide feature-based attention towards the discrimination target while at the same time a saccade had to be prepared either towards or away from the discrimination target according to a central arrow cue. The constant color greatly improved discrimination performance, even when the location of the saccade target and the discrimination target did not coincide. In contrast to previous studies, however, we also observed improved performance when the discrimination target was presented at a constant position. Our findings are discussed in terms of interactions between spatial attention, feature-based attention and attention-for-action.

53.414 **Attentional modulation of saccadic inhibition during scene viewing**

Mackenzie Glaholt[1](mackenzie.glaholt@gmail.com), Eyal Reingold[1]; [1]Department of Psychology, University of Toronto Mississauga

Participants viewed eight-item arrays containing colour photographs from two categories of scenes. Four of the eight photos depicted natural landscapes (Nature scenes) and the other four depicted urban environments (Building scenes). Participants were instructed to memorize scenes from one of the two categories (i.e., the relevant category) in preparation for a later recognition memory test. A gaze-contingent manipulation was employed such that while a scene was being fixated, the border around it flickered briefly from black to white with a random interval between flickers ranging from 400 – 600 ms. We computed the likelihood of a saccade being initiated in the period following the flicker. Consistent with prior research, we observed a saccadic inhibition effect with a minimum in saccadic activity occurring roughly 97 ms following the flicker. Importantly, the saccadic inhibition effect was stronger in magnitude and duration when the eye was fixated on a relevant scene compared to an irrelevant scene. This finding corroborates and extends prior research on the relationship between saccadic inhibition and attention in reading, and demonstrates that the saccadic

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inhibition effect can provide an index of the deployment of attention during scene viewing. Implications of these findings for theories of attention and oculomotor control are discussed.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

53.415 **The Role of Photographic Clarity and Blur in Guiding Visual Attention**

Sarah C MacDonald[1](sarahmacdonald91@gmail.com), James T Enns[1]; [1]Department of Psychology, University of British Columbia

Although visual artists and photographers know that a viewer's gaze can be guided by selective use of image clarity and blur, there has been little systematic research. For example, there are hints that clarity and blur may play different roles in guiding attention when they are implicit cues to attention (Veas et al., CHI 2010) versus when they are the explicit targets of a task (Kosara et al., VRVis 2001) but systematic comparisons have not been done. In this study, 24 participants performed two eye-tracking tasks with the same naturalistic photographs, a recognition memory task in which manipulated image regions were not mentioned to participants (Experiment 1), followed by a visual search task in which these regions were explicit targets (Experiment 2). The results from the implicit task in Experiment 1 showed that fixations occurred more rapidly and frequently to a local region of clarity in a photo than to a comparable blurred region. However, this bias was completely reversed in the visual search task of Experiment 2, where fixations and manual responses were faster to targets that were blurred than to those that were sharp. These findings emphasize that the spontaneous tendency of viewers' eyes to seek out regions of clarity in a photo does not mean image blur is ignored. Rather, the exquisite sensitivity to blur is evidence that these signals are integral to the strong association in everyday vision between image clarity (achieved through accommodation, vergence, and foveation) and focused attention (achieved through directed gaze).

Acknowledgement: NSERC

53.416 **Eye movement patterns during judgments of absolute distance in natural environments**

Courtney Wallin[1](courtneypwallin@gmail.com), Daniel Gajewski[1], John Philbeck[1]; [1]The George Washington University

The nearby ground plane acts as a crucial reference frame for judging both near and far distances. However, it is unclear what role eye movements play in establishing this reference frame. Is the immediate ground plane preferentially fixated? What eye movement strategies do observers prefer? Do different response modes (i.e., action-based or not) elicit different gaze behaviors, and are some eye movement patterns associated with better performance? To address these questions, we monitored eye movements while participants viewed targets (2.75-5 m distant) for 3-5 seconds. In Experiment 1, observers used blindwalking or verbal report (between groups) to judge distances; eye movements were unconstrained. While the target was fixated at least once on 98% of the trials, the nearby ground plane was only fixated 50% of the time. When this region was fixated, viewing patterns varied greatly: the number of fixations per entry into the region ranged from 1 to 8, with some observers seemingly counting units between themselves and the object. Surprisingly, others adopted a steady gaze strategy (34% of trials), wherein the target, once fixated, was the only region fixated. Accuracy was equivalent between groups (mean error = -9%) and no differences in eye movement behaviors existed between response measures. Experiment 2 focused on the role of two particular eye movement strategies, with blindwalking as the response mode. Participants began each trial fixating the target; one group maintained a steady fixation on the object and the other was encouraged to scan around. Accuracy was equivalent between groups (mean error = -14%). In sum, results indicate that observers engage in a variety of gaze behaviors when judging absolute distances but these are not modulated by response mode. Furthermore, response accuracy is independent of viewing strategy, at least when multiple extended glimpses of the environment are available.

53.417 **Visual search in natural scenes: fixation positions predicted by local color properties**

David H. Foster[1](d.h.foster@manchester.ac.uk), Kinjiro Amano[1], Matthew S. Mould[1], John P. Oakley[1]; [1]School of Electrical & Electronic Engineering, University of Manchester, Manchester, UK

Searching for an object in the world around us is an everyday experience. Success depends on many factors, including the structure of the scene being searched, the nature of the object being sought, and, critically, where we look. Color has been found to be influential in such tasks, but primarily as a way of defining differences between a target and its background, and usually with abstract geometric displays rather than with more natural scenes. The aim of this study was to determine to what extent the local color properties of natural scenes can predict the distribution of observers' fixation positions. Seven observers with normal color vision and visual acuity were presented with 1-s images of 20 natural scenes, each subtending 17x13 deg visual angle on a color monitor. The target to be detected was a shaded gray sphere, subtending 0.25deg, embedded randomly in the scene and matched in mean luminance to its local surround to avoid producing accidental luminance cues. Observers' gaze position was simultaneously monitored with an infra-red video eye-tracker sampling at 250 Hz. The spatial distribution of observers' fixations was fitted by linear combinations of the spatial distribution of local color properties, namely lightness and the red-green and blue-yellow components of chroma. Goodness of fit was quantified by the proportion of variance explained by local color properties, after adjustments for degrees of freedom in the fit and smoothing of the distributions. It was found that when averaged over scenes the proportion of the variance explained was 36-40%, but there were large differences between scenes, and for some the proportion reached 75-84%, depending on the degree of smoothing. Despite a common assumption that achromatic features dominate gaze behavior, the present results suggest that local color information can be at least as important in influencing where we look.

Acknowledgement: EPSRC EP/F023669/1

53.418 **Linking eye fixation strategies to experience in visual statistical learning.**

Dmitriy Lisitsyn[1](dmitriy.lisitsyn@schepens.harvard.edu), Henry Galperin[2], Jozsef Fiser[1]; [1]Volen Center for Complex Systems, Brandeis University, Waltham MA, [2]Department of Psychology, Brandeis University, Waltham MA

Linking eye-movement to visual perception or to learning has been notoriously difficult due to the fact that the visual stimulus is either too simplified providing no insights to the true nature of learning or with too rich input, the process of learning becomes intractable. Visual statistical learning (VSL) provides an ideal framework for such studies since it uses stimuli with precisely controlled statistics and regular spatial layout. We used the classical VSL paradigm combined with eye tracking and asked whether this controlled implicit learning paradigm allows following the contribution and development of eye movements during the learning process. Stimuli were based on 12 simple shapes combined into six base-pairs. From this alphabet, each scene was composed by randomly selecting three of the base-pairs and juxtaposing them on a grid to generate over 140 scenes that were shown sequentially for 3 sec each on a large 4*3 feet screen while the subjects' eye movements were monitored. Subjects had no task beyond attentively observing the scenes. Post practice, subjects were given a test with multiple trials, where they had to choose between true building base-pairs and random combination of pairs based on their judgment of familiarity. Subjects typically became familiar with the base-pairs to a different degree, showing a wide variation of success in choosing the true base-pair over a foil. This distribution of percent correct values was correlated with various measures of eye-movement. We found a correlation between the amount of eye-fixations and the total fixation time on the shapes of the highly learned pairs versus the pairs that weren't learned. These results provide a first indication that not only in highly explicit cognitive tasks, but even in implicit observational tasks, eye movements have a tight link to the acquired knowledge of the visual scenes.

53.419 **Eye movements during object recognition in a case of integrative visual agnosia**

Charles Leek[1](e.c.leek@bangor.ac.uk), Candy Patterson[1], Robert Rafal[1], Filipe Cristino[1]; [1]Wolfson Centre for Clinical and Cognitive Neuroscience, School of Psychology, Bangor University

This study reports some of the first evidence about eye movement patterns during object recognition in a case of acquired visual agnosia. The eye movements of an integrative visual agnosic patient IES and controls were recorded during two object recognition tasks: Object naming and novel object recognition memory. Differences in the spatial distributions of IES's fixations, and fixation dwell times, were correlated with recognition performance in object naming. In addition, in both object naming and novel

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object recognition memory, the patient showed abnormal saccade amplitudes with a bias towards shorter saccades. In contrast, the patient showed normal directional biases and sensitivity to low-level visual saliency. It is suggested that this bias towards low amplitude saccades, and the aberrant spatial distribution of fixations, reflects a breakdown in the functional link between bottom-up and top-down guidance of eye movements during shape perception.

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53.420 Saccadic luminance detection across visual space

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Around the time of saccadic eye movements, visual performance is deteriorated in multiple ways in visual space, while performance at the saccade target location is enhanced. In this study, we investigate luminance detection across a large part of visual space during saccades. Subjects seated in an illuminated room detected a brief achromatic probe stimulus while executing a 20 degree rightward saccade. The probe was a 1 x 1 degree square of varying luminance that flashed for a single frame (6.67 ms) on a gray background (2.74 cd/m2) of a CRT monitor. The probe appeared randomly at 13 discrete locations, spaced 4 degrees apart, covering 48 degrees of visual space along the horizontal meridian, and encompassed the fixation point and the saccade target. Both the fixation point and the saccade target consisted of 0.5 degree diameter green circles that were subjectively equiluminant to the background. The cue to initiate the saccade occurred randomly within a 1000 ms time window, and was provided by the simultaneous offset and onset of the fixation point and saccade target, respectively. Luminance detection thresholds were obtained at multiple saccadic epochs by means of a generalized linear model using maximum likelihood estimation. Thus far, more than 40,000 saccadic trials have been collected from each of two subjects. For both subjects we find a consistent pattern of luminance detection thresholds as a function of time and space. In particular, thresholds at peripheral locations were substantially elevated immediately at saccade onset. In contrast, detection thresholds within a region containing the fovea and the spatiotopic location of the saccade target remained relatively low, suggesting a preferential processing of this region throughout saccadic eye movements.

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53.421 Gaze behavior during motion parallax.

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Motion parallax, or differential image motion resulting from movement of the observer, provides powerful cues for both segmentation and depth perception. During such observer movement, reflexive eye movements occur to counter the foveal image motion. We previously (JOV 2011) measured depth and segmentation performance from motion parallax while minimizing eye movements by keeping a defined fixation point. Here we examine the pattern and influence of eye movements during motion parallax, under different fixation conditions. Observers performed lateral head translation while an electromagnetic tracker recorded head position. Stimuli consisted of random dots, whose horizontal displacements were synchronized proportionately to head movement by a scale factor (syncing gain), and were modulated to generate motion. Eye movements were recorded using a remote optical eye-tracking system. First we measured the ability of observers to maintain fixation during depth and segmentation tasks, using a defined fixation point. The fixational behavior was highly imperfect, with eye position varying around the target fixation point in synchrony with head movement. Thus the reflexive eye movements only compensate for a fraction of the retinal slip due to head movement. With free fixation, segmentation performance was largely unaffected, but depth perception deteriorated at high syncing gains. The fixation pattern again exhibited imperfect cancellation of retinal slip, with variation in synchrony with the head movement. Furthermore during the depth task, observers primarily fixated on the virtual surfaces, whereas during the segmentation task fixation was mostly at their boundary. The amplitude of eye movements was independent of the actual stimulus motion. Thus reflexive eye movements during motion parallax are imperfect, but psychophysical performance is affected only in specific conditions. These results illustrate how gaze behavior can be task-dependent, and suggest that during natural motion parallax observers fixate on surfaces for depth information, whereas they fixate along boundaries for segmentation.

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53.422 Experience Visual Qualia without Conscious Percept?

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In the phenomenon of blindsight, people can exhibit above-chance performance in responding to visual stimuli, which indicates there is a possible dissociation between visual awareness and performance. Moreover, it is possible that observers tend to degrade their awareness threshold while they are under-confident due to the inability of perceiving targets clearly. In Experiment 1 (n = 3), we presented observers with drifting plaids composed of two superimposed gratings whose direction differed by 180°, the orientation of which was varied by 10, 20, 30, and 45°. Perceptual responses (i.e., perceived component or pattern motion) and eye movement (EM) patterns were recorded under binocular- and dichoptic-viewing conditions. In Experiment 2 (n = 3), we used only dichoptic viewing and utilized binocular switch suppression technique (i.e., repeatedly switching conflicting images between the eyes) to render drifting gratings temporarily invisible. Furthermore, the contrast level of drift gratings was varied. Perceptual responses and EM patterns were recorded. Observers had to indicate their visual experience categorically (i.e., clear image, almost clear image, weak glimpse, or not seen) at the end of each trial. During binocular viewing, observers' perceptual responses were consistent with their EMs. Under the dichoptic-viewing condition, observers perceived component motion frequently. There was no clear dissociation between perceptual responses and EMs. However, the optokinetic nystagmus rate (OKN) increased during dichoptic viewing. In Experiment 2, EMs were dissociable from observers' perceptual responses even when they reported no awareness of moving gratings. Moreover, observers reported visual experience as being graded rather than "all-or-none". Our findings indicate observers' visual awareness and performance can be dissociated, and they tend to underestimate their visual capacity when conditions are difficult. Understanding how the visual system operates with or without visual awareness by using different psychophysical manipulations will allow us to use measurable techniques to trace the fingerprints of the neuronal correlates of consciousness.

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53.423 What eye-tracking can tell us about multiple-target visual search

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Many real-world visual searches contain multiple targets (e.g., a medical X-ray may have multiple tumors visible), and multiple-target searches present additional challenges beyond those of single-target searches. Specifically, finding one target can reduce the likelihood of finding a second target in the same array (a phenomenon dubbed 'satisfaction of search'; Tuddenham, 1962), and this likelihood can be modulated by external factors such as anxiety (e.g., Cain, Dunsmoor, LaBar, & Mitroff, 2011). Multiple-target search effects have been examined in radiology (see Berbaum, et al., 2010) and in cognitive psychology (e.g., Fleck, Samei, & Mitroff, 2010), yet key questions remain about the underlying mechanisms. To address these questions, we utilized eye-tracking to provide insights into why targets are missed in multiple-target searches. Participants searched for perfect-T targets among pseudo-L distractors, with displays containing either 1 or 2 targets. Finding a first target in a multiple-target trial did not influence overall search performance (e.g., no change in average fixation time on distractors). However, analyses of the trials where the second target was missed revealed that: (1) second targets were not fixated on more than half of the multiple-target trials, and (2) when they were fixated, the average fixation length fell below the median fixation length for distractors. Collectively, this suggests that satisfaction of search is due, in part, to searchers not finding and fixating second targets long enough to determine their identity. These results present a different picture than previous radiological findings (Berbaum et al., 1998; Samuel et al., 1995), which found that missed

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targets were fixated the same amount of time regardless of whether or not another target had been detected. Satisfaction of search remains a very real problem, and these data suggest that the type of search and the searcher's level of expertise may both play an important role.

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Eye movements: Fixational, models and methods

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

53.426 Time course of spatial frequency sensitivity during natural fixation

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Since the original hypothesis that analysis of a visual scene proceeds from a global, coarse scale to a more detailed and finer one (Navon 1977), many studies have examined the temporal course of visual processing. Most studies have used conditions in which stimuli are flashed while observers maintain steady fixation. During natural viewing, however, stimuli are brought into the fovea by saccades, which are then followed by microscopic (fixational) eye movements. Fixational eye movements have been shown to enhance high spatial frequencies (Rucci et al. 2007) and may therefore contribute to a coarse-to-fine processing of the scene. To investigate the dynamics of visual processing during natural fixation, we used a gaze-contingent display procedure, in which stimuli were presented following a saccade. Stimuli consisted of gratings embedded in noise, which were either briefly presented at the onset of fixation (early condition), or ramped up gradually during the course of fixation (late condition). Two different patterns of results were obtained depending on the characteristics of the stimulus. With a 1 cycles/deg grating, performance was significantly better in the early condition than in the late one. Conversely, with an 11 cycles/deg grating, performance was higher in the late condition. Our results suggest that the normal alternation between macroscopic and microscopic eye movements contribute to a coarse-to-fine dynamic of visual processing during natural fixation.

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53.428 Modulation of visually-driven cortical activity by microsaccades and voluntary saccades.

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Introduction: Microsaccades are miniature saccades that occur frequently and involuntarily during fixation. Microsaccades cause sudden and rapid changes to the retinal image, but we do not perceive motion or blur. Both psychophysical performance and neural activity are transiently suppressed by large, voluntary saccades, a phenomenon called saccadic suppression. This study tested whether cortical activity, measured with fMRI in humans, is likewise suppressed with microsaccades. Methods: Saccadic suppression was tested by comparing visually-evoked response amplitudes with and without saccades. In Expt 1, subjects made microsaccades while fixating a stable target. In Expt 2, subjects made large (14 deg) voluntary saccades to a peripheral target. In both experiments, a task-irrelevant stimulus appeared at various intervals relative to saccade onset. fMRI response amplitudes were measured coincident with: 1) saccades that occurred in the absence of a visual stimulus; 2) visual stimuli that occurred in the absence of a saccade; and 3) stimuli with onset times within 100 ms of a saccade. Analysis focused on subregions of V1 that responded to the stimulus in the absence of saccades, but that showed no evidence of saccade-related activity in the absence of visual stimulation. Results: In Expt 1, responses to the visual stimulus were larger when the stimulus appeared within 100 ms of a microsaccade relative to when the stimulus appeared during stable fixation. This enhancement could not be attributed to the summation of microsaccade-alone and stimulus-alone activity. In Expt 2, visual responses were smaller around the time of a large, voluntary saccade. Conclusions: Saccadic suppression predicts a decrease in response amplitude, yet we observed enhanced visual activity. This enhancement is not likely due to metabolically-demanding inhibitory activity, because we observed a reduction of visually-driven activity in conjunction with large voluntary saccades. Our results suggest that perisaccadic changes in visual responses depend on eye movement metrics.

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53.429 Microsaccades and blinks trigger illusory rotation in the "Rotating Snakes" illusion

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Certain repetitive arrangements of luminance gradients elicit the perception of strong illusory motion. Among them, the "Rotating Snakes" Illusion has generated a great amount of interest in the visual neurosciences, as well as in the public. Prior evidence indicates that the Rotating Snakes Illusion depends critically on eye movements, yet the specific eye movement types involved and their associated neural mechanisms remain controversial. According to recent reports, slow ocular drift, -- a non-saccadic type of fixational eye movement -- drives the illusion, whereas microsaccades produced during attempted fixation fail to do so. Here we asked subjects to indicate the presence or absence of rotation during the observation of the illusion, while we simultaneously recorded their eye movements with high precision. We found a strong quantitative link between microsaccade and blink production and illusory rotation. These results suggest that transient oculomotor events such as microsaccades, saccades and blinks, rather than continuous drift, act to trigger the illusory motion in the Rotating Snakes Illusion.

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53.430 Effect of image statistics on fixational eye movements

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Under natural viewing conditions, small movements of the eyes prevent the maintenance of a steady direction of gaze. It is unclear how the spatiotemporal content of the fixated scene has an impact on the properties of miniatures, fixational eye movements. We have investigated the characteristics of fixational eye movements recorded while human subjects are instructed to fixate natural statistics random textures (Motion Clouds) in which we manipulated the spatial frequency content. We used long presentations (5 sec) of Motion Clouds stimuli (Schrater et al. 2000) of varying spatial frequency bandwidths (Bsf) around different central spatial frequency (Sf0). We found that central spatial frequency has an effect upon microsaccadic eye movements. In particular, smaller saccadic amplitudes were associated with high spatial frequencies, and larger saccades with low spatial frequencies. Broadening the spatial frequency bandwidth also changed the distribution of microsaccade amplitudes. A lower spatial frequencies, larger Bsf resulted in a large reduction of microsaccades amplitude while fixation behavior for high spatial frequencies texture was not affected. Relationship between microsaccade rate and intersaccadic timing was also dependent upon Bsf. These results suggest that the spatial frequency content of the fixated images have a strong impact upon fixation instability. Paul R. Schrater, David C. Knill and Eero P. Simoncelli (2000) " Mechanisms of visual motion detection" Nature Neuroscience 3, 64 - 68.

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53.431 Microsaccadic efficacy and contribution to foveal and peripheral vision

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Our eyes move constantly, even when we try to fixate our gaze. Fixational eye movements prevent and restore visual loss during fixation, yet the relative impact of each type of fixational eye movement remains controversial. For over five decades, the debate has focused on microsaccades, the fastest and largest fixational eye movement. Some recent studies have concluded that microsaccades counteract visual fading during fixation. Other studies have disputed this idea, contending that microsaccades play no significant role in vision. The disagreement stems from the lack of methods to ascertain the precise effects of microsaccades on vision versus those of other eye movements, as well as a lack of evidence that microsaccades are relevant to foveal vision. Here we developed a novel generalized method, based on mathematical techniques previously employed to assess the strength of connection of two neurons, to determine the precise quantified contribution and efficacy of microsaccades to restoring visibility as compared to other eye movements. Our results indicate that microsaccades are the greatest eye movement contributor to the restoration of both foveal and peripheral vision during fixation. Our method to calculate the efficacy and contribution of microsaccades to perception can determine the strength of connection between any two physiological and/or perceptual events, providing a more powerful estimate of causality than correlation; thus we anticipate wide-ranging applications in neuroscience and beyond.

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53.432 **Cortical activity in visual cortex coincident with microsaccades**

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Purpose: Our eyes are in constant rapid motion, and each such movement (saccade) generates a displacement of the visual image on the retina. Despite these displacements, our visual perception remains stable. It has long been hypothesized that the visual system maintains perceptual stability by compensating for these displacements by means of extraretinal information which it receives from oculomotor areas (corollary discharge). Most of the procedures previously used to study the corollary discharge employed peripheral cues as saccade targets. Such peripheral stimulation confounds the visual activity related to extraretinal neural processes with that related to retinal stimulation. The purpose of this research was to circumvent this confound by using involuntary small saccades (microsaccades) recorded in complete darkness, allowing us to avoid peripheral visual stimulation. Using this procedure we are able to demonstrate visual activation during saccade execution which is unrelated to retinal stimulation. Method: We scanned subjects either while viewing a large, high contrast radial checkerboard (control), or while fixating on a small dot in an otherwise completely dark environment (main experiment). Cortical responses were measured with fMRI, time-locked to microsaccade onset. Results: In the control experiment, several striate and extrastriate visual areas showed microsaccade-related activity. In the main experiment most of the early visual activity was not evident but significant responses remained in dorsal visual areas V3A and V6. Conclusions: Activity in the control experiment (static stimulus) was likely the result of visually-evoked neural responses due to retinal displacement. The results of the main experiment cannot be attributed to retinal slip because it was conducted in complete darkness. Rather, visual activity in the main experiment may be related to corollary discharge signals fed back to visual cortex at the time of each eye movement.

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53.433 **Distributed processing in a sequential scanning task**

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Current models of eye movement control are derived from theories assuming serial processing of single items or from theories based on parallel processing of multiple items at a time. This issue has persisted because most investigated paradigms generated data compatible with both serial and parallel models. Here we study eye movements in a sequential scanning task, where stimulus n indicates the position of the next stimulus n+1. We investigate whether eye movements are controlled by sequential attention shifts when the task requires serial order of processing. Our measures of distributed processing in the form of parafoveal-on-foveal effects, long-range modulations of target selection, and skipping saccades provide evidence against models strictly based on serial attention shifts. We conclude that our results lend support to parallel processing as a strategy for eye-movement control.

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53.434 **Optimization of Fixations during Scene Viewing**

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Previous research has suggested two ways in which the eyes move during scene viewing (Henderson & Smith, 2009): (i) process monitoring proposes that decisions regarding when to move the eyes are based on the continuous processing of the viewed scene, and (ii) autonomous control suggests that these decisions are driven by some general internal strategy such as a timer. We investigated these views by presenting global scene transitions. Participants' eye movements were monitored as they were presented with two images depicting natural scenes, each for 4.5 s, thus introducing a global transition as one scene changed to the other. They were then presented with an object from one of the two scenes, and asked to identify the scene that contained the object. We observed two distinct groups of fixations when the scene transition was introduced. The End-Early group (32% of the fixations) ended less than 100ms after the transition, exhibited shorter fixation durations (mean±SEM of 197.06±16.23ms vs. 249.53±11.16ms for baseline) in the first fixation, and moved towards the center of the scene in the second fixation. The End-Late group ended more than 100ms after the transition, exhibited longer fixation durations (329.19±17.29ms vs. 252.36±9.01ms) during the transition, and moved towards the center in the first fixation. This suggests that immediately after a transition, End-Late fixations aborted the previously-programmed saccade, and reprogrammed to the center, which may serve as a vantage point to re-start scene exploration (Tatler, 2007). For the End-Early fixations, the transition probably occurred too late for saccade reprogramming, which caused the pre-planned eye movement to be executed, before moving to the center. This suggests that eye movements were optimized during viewing, i.e. they were planned and executed while continuously monitoring the visual scene, which supports process monitoring. We did not find any evidence of timer control in our data.

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53.435 **Continuous Time Infomax Models of Oculomotor Control**

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Recent models of oculomotor control have been successful at describing saccade velocity profiles using optimal control principles. Some models postulate that the eyes minimize the expected deviation from a target end point (Minimum Variance models). Other models postulate that eye movements minimize the time required to reach the target point (Minimum Duration models). These models have a common assumption that the goal of oculomotor control is to reach target points. Not surprisingly, much of the empirical data used in these models is based on tasks in which the explicit goal is for the eyes to move to predifined target end points. However, such tasks seldom occur in daily life. Instead, the eyes typically play a supportive role, providing other actuators (e.g., the hands) with the information they need to efficiently achieve their goals (e.g., grasp objects). Here, we use a rapid-pointing task to study eye movement in different conditions where the eyes serve either a supporting role (where the reward depends on the hand endpoint) or an executive role (where the reward depends on the fixation endpoint). Our results suggest that Minimum-variance and Minimum-duration models cannot account for key properties of the eye movements observed in our data. To address this issue, we present an alternative class of models (Infomax models) in which the eyes move to maximize the information needed to achieve goals. The approach relies on a novel algorithm (PIC2) developed at our laboratory to find approximate solutions to continuous time partially observable stochastic optimal control problems. We present our progress solving Infomax Control problems and show how they explain the complex saccadic movements observed in our experiments.

53.436 Bayesian saccade planning as a universal visuomotor principle

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During reading, saccadic eye movements aiming at word centers are generated to shift words into the fovea for lexical processing. However, where the eyes land within words is, on average, a function of the distance of the center of the target word from the prior fixation location (i.e., the launch site). In effect, the optimal first-fixation position at the center of new words is realized only from an optimal launch-site distance, while close or distant word centers are systematically over- or undershot (McConkie et al., 1988). A similar pattern was found in saccades aiming at single targets, but the launch-site contingent shift of saccadic end points appears to be much smaller than in reading (Kapoula, 1985). Here we show that the launch-site effect in both paradigms can be quantitatively reproduced by a recently developed Bayesian model of saccade planning (Engbert & Krügel, 2010). The model is based on the assumption that subjects use Bayesian estimation for optimal computation of target position based on noisy sensory information. We demonstrate that the pronounced launch-site effect in continuous reading compared to single saccade paradigms is a consequence of less precise visual information about the location of the saccade target. Our results bridge the gap between basic oculomotor research and research on eye movements in reading. Implications for reading theories are discussed.

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53.437 Parameter distribitions of eye-movements based on 1,000,000 trials

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Eye movement metrics, such as fixation duration, frequency and saccade amplitude are often reported in terms of means per subject or condition, and are subsequently analyzed by parametric statistics. Yet, when such metrics are plotted as a frequency distribution, the resulting histogram is heavily skewed to the right, violating one of the primary rules of parametric testing; the data should be normally distributed. Here we explore how common skewed distributions are by analyzing eye movements during a number of cognitive experiments that have been conducted within the Concordia Vision Lab over the past few years. Eye position was monitored using an SR Research Eyelink 1000 with a minimum sample rate of 500Hz, with a minimum average calibration accuracy of .5 deg. (max. error of 1 deg.). Eye movement recordings from multiple tasks were collected from participants, whose ages ranged from 18 months to 78 years, using consistent definitions of fixations and saccades. Tasks included scene perception, visual search, face emotion recognition, and empathy response (all stimuli and subsequent eye movements are available to download at http://cvl.concordia.ca). We find that all tasks show a similar skewed distribution in fixation duration, frequency and saccade latency and amplitude. Accordingly, we show that the median, and not the mean, is the measure of central tendency that best represents the distribution. Subsequent parametric analysis of these data can use there be conducted with median values. Finally, we show how more subtle changes in the distribution can be described using parameter fitting eye movement distributions with a Weibull curve (which shows the best goodness-of-fit measures to eye movements). We find little change in the shift parameter, but large differences in the scale parameter. Future investigations of eye movement recordings should therefore take further care in properly characterizing the data they have collected prior to their analyses.

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53.438 Visual processing in the primate superior colliculus during freeviewing of natural stimuli

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The superior colliculus (SC) is a layered midbrain structure comprised of several registered maps, ranging from purely sensory retinotopic representations in the most superficial layers (SCs), to sensorimotor representations linked to the control of eye movements in the intermediate layers (SCi). The superficial collicular layers receive visual inputs directly from the retina and from early visual cortex and project to sensorimotor neurons in the SCi. We investigated the spatiotemporal processing of visual signals in the SC by combining single-unit monkey electrophysiology and computational modeling of bottom-up visual processing. We recorded extracellular spike trains from 1-4 neurons simultaneously in the SCs and SCi (n=20 visual, n=27 visuomotor) of two monkeys. In a given session, a series of tasks requiring the monkey to hold fixation and make saccades were first used to characterize each neuron's receptive field and response properties. The monkey then freely viewed videos (3-20 seconds long) and still images (displayed for 10 seconds) of natural outdoor scenes presented on a large, high-definition display (~80x40 degree field of view; 1920x1080 pixels; 30Hz). Offline, recordings of the monkey's eye position were used to replay to a computational model of visual processing in the SC the exact, gaze-contingent display that impinged onto the monkey's retina. The model consists of a 2-D network of excitatory and inhibitory leaky-integrator neurons with local excitatory and local and long-range inhibitory connections. Visual cortex and retinal inputs are modeled by filtering the video for motion, contrast, edges and color opponency at multiple spatial scales. These sensory signals merge in the model SC creating a retinotopically-organized, feature-agnostic representation of candidate visual targets (saliency map). Results indicate a signifiant correlation between the model and neural spike trains for a subset of neurons collected.

53.439 Scanpath similarity in sequential sensorimotor tasks: Comparing a sub-action sequenced linear distance method to string edit methods

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Measures of scanpath similarity across different conditions or participants are essential in many research domains. Traditional string-edit methods compare fixations within a scanpaths according to their numerical and more recently temporal position within the paths. These procedures are reasonable when the to-be-compared scanpaths are executed in response to a relatively stable environment such as comparing scanpaths during picture viewing. In sequential sensorimotor tasks, participants actively change their environment while extracting task-relevant visual information with the eyes and these dynamical changes differ across trials. Some sub-actions are for instance elongated and accompanied by more fixations while others are shortened and accompanied by fewer fixations than during prior execution. Therefore, traditional methods for determining scan path similarity are not adequate in this case. The functional units of sequential sensorimotor tasks are the sub-actions in which the task is structured. Based on these sub-actions, a functional matching procedure for determining scanpath similarity had been developed (Foerster et al., 2011). This procedure evaluates the similarity of scanpaths according to the linear distances between fixation locations that have been performed during the same sub-action of a sensorimotor task. Distance values are evaluated by testing them against random distance values calculated from the same scanpaths. The method reveals whether participants look at similar locations when they are engaged in the same sub-action compared to different sub-actions. Extending our earlier work, the functional matching procedure was applied to fictitious scanpaths as well as to real scanpaths that had been recorded during a high-speed stacking task. The strength of the method could be demonstrated by comparing it with traditional string-edit methods.

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53.440 Fixation patterns as point processes

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Sequences of eye movements are composed of fixations and saccades. In a lot of cases, what is of interest is essentially where in space fixations occur: what is relevant is the point pattern formed by successive fixations. This suggests that the analysis of eye movements could benefit from models of point processes developed in spatial statistics, including latent Gaussian fields. We show that these are a valuable tool for the understanding of eye movement patterns. We focus on questions occuring in the study

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of overt attention. When subjects select what part of a stimulus to attend, several factors are often at work. Where people look will depend on what information they need, on what the stimulus is, but also on things less directly relevant to the analysis: for example, the common bias for central locations over peripheral ones. To understand the strategies at work, one must be able to somehow separate these different factors. One might ask, for example, what part of fixations on natural images can be explained by the presence of high contrast edges, or other low-level features. But how do we formalise the idea that the pattern of fixations is partly due to contrast, and partly not? Based on techniques borrowed from Functional Data Analysis we formulate a framework for the analysis of fixation locations. This allows us to describe fixation distributions in a non-parametric way. To introduce some regularity we assume that fixation distributions do not vary completely freely but are functions of some known variables, based on the stimulus or on trial history. The use of log-additive decompositions lets one separate out the various factors at work, and allows for a direct evaluation of their relative influence.

Acknowledgement: German Ministry of Research

Multisensory processing: Visuo-auditory interactions

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

53.444 Matching voice and face identity from static images

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Previous research has suggested that people are unable to correctly choose which unfamiliar voice and face belong to the same person, based on a static image of the face. Here, we present evidence that people can perform this task with greater than chance accuracy. On each trial, participants saw pictures of two, same-gender faces, while simultaneously listening to a recording of the corresponding voice of one of the faces; participants had to choose which of the faces they thought belonged to the same person as the recorded voice. All of the stimuli were drawn from Caucasian undergraduate students (mean age: 21). In Experiment 1, the visual stimuli were frontal headshots (including the shoulders and neck) and the auditory stimuli were recordings of spoken sentences. Experiment 2 used the same auditory stimuli as Experiment 1 but used pictures in which only facial information (excluding the shoulders and neck) was visible. Experiment 3 used the same pictures as Experiment 1 but the auditory stimuli consisted of recordings of a single spoken word. In Experiments 1 and 2, people could choose, at better than chance levels, which faces and voices belonged to the same person. In Experiment 3, where less auditory information was available, performance was at chance levels. These results suggest that people do have the ability to correctly infer facial characteristics from vocal characteristics, given sufficient information. The mechanism underlying this ability is not currently clear, since additional analyses found no evidence that participants were correctly choosing based on matching basic physical traits such as age, weight, height and attractiveness. Previous negative findings may have been due to insufficient auditory information or too homogenous a sample of faces and voices. With ample auditory information and a sufficiently heterogeneous sample, people can choose what face and voice go together, based on static pictures.

Acknowledgement: NSF

53.445 Cross-modal transfer without concurrent stimulation: a challenge to a hidden assumption

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Most cross-modal adaptation studies have a hidden assumption that any cross-modal effects at perceptual levels require concurrent bimodal stimulation. The current study examined temporal rate adaptation to test whether an aftereffect (1) could be induced within vision (V-adaptation/V-test) and audition (AA), (2) would transfer from audition-to-vision (AV), and from vision-to-audition (VA), and (3) would be enhanced in bimodal conditions (AV-AV). Participants were trained, using feedback, to discriminate the perceived rapidity of repetitive auditory, visual, or audiovisual stimuli presented at a range of randomly ordered frequencies (3.25-4.75 Hz) relative to a learned standard frequency (4 Hz). Afterwards, participants were exposed to 30 adaptation stimuli presented at 3 or 5 Hz, while performing a dummy task of counting gaps in the stimulus trains. The adaptation was either in the same modality/modalities as the training, or across modalities. After the initial training and adaptation phases, adaptation and test trials (which were identical to the training trials, but without feedback) were presented in 20 alternating blocks of 7 trials each. In all conditions, there was a significant negative aftereffect, such that stimuli were perceived to be slower after exposure to the fast adaptation stimuli, and the reverse. Remarkably, this occurred even in the AV and VA cases, when vision and audition were never presented concurrently. The magnitudes of the aftereffects were not consistent with predictions based on the reliabilities of the signals; although vision was the less reliable modality in time, it did not shift significantly more than audition, and audition did not induce larger shifts than vision. The shift in the AV-AV case was also not predictable based on the within-modal cases. These findings suggest that sensory information can have perceptual influences beyond the modality in which it is presented. They also place constraints on models of multisensory interactions.

53.446 Implicit multisensory statistical learning influences visual perceptual selection

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Can unconscious knowledge influence what we see? We present evidence for effects of rapid implicit learning of arbitrary crossmodal associations on visual perceptual selection. We measured perceptual selection with binocular rivalry, in which incompatible images presented separately to the two eyes result in a perceptual alternation between the images. Although there is evidence that sounds that are temporally (Kang & Blake, 2005), directionally (Conrad et al., 2010), or semantically (Chen et al., 2011) congruent with one of a pair of rivalrous visual percepts can promote dominance of the congruent percept, these effects could be attributed to explicit knowledge and attentional control. Here, we show that implicit audio-visual statistical learning (Fiser & Aslin, 2001, Seitz et al., 2006) influences perceptual selection. During a brief (10-minute) passive exposure phase, subjects were presented with rapid streams of images (gratings and simple patterns) and sounds (pure tones and chords). For half of the stimuli, a given sound was consistently paired in time with a given image, facilitating an association between the sound and image. The remaining sounds and images were randomly paired throughout the exposure phase. Audio-visual pairings were randomly assigned and counterbalanced across subjects. In a subsequent rivalry test, subjects were presented with combinations of sounds and rivalrous images, all from the exposure phase. At the onset of rivalry, subjects were more likely to perceive an image when it was presented with its auditory match than when it was presented with a non-matching sound. Importantly, these effects of implicit learning on rivalry did not correlate with subjects' conscious knowledge of the audio-visual pairings, as assessed in a separate explicit learning test for each subject. Our results indicate that our prior knowledge—even that which is recently acquired and unconscious—helps us resolve ambiguity in the visual world.

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53.447 Temporal frequency limits for within- and cross-attribute binding in vision and audition

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Temporal synchrony provides a critical cue to bind multiple sensory signals processed in parallel. The speed of temporal binding of sensory signals, processed in parallel, can be psychophysically estimated from the critical temporal frequency beyond which observers cannot discriminate the temporal relationship between two oscillating stimulus sequences (i.e., whether A is in synchrony with X or Y for a sequence pair of ABABAB… and XYXYXY…). In vision, it has been reported that the upper temporal limits for within-attribute binding are relatively high (8-20 Hz), while those for cross-attribute binding are relatively low (~2.5 Hz) (Fujisaki & Nishida, 2010, Proc Biol Sci.). Here we examined whether similar results can be observed in audition. In the auditory within-attribute condition, an alternation of 1108.8 Hz and 523.2 Hz pure tones was paired with an alternation of

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493.9 Hz and 293.7 Hz pure tones. Participants judged whether the 1108.8 Hz was in phase with 493.9 Hz or 293.7 Hz. In the auditory cross-attribute condition, an alternation of high-pitched and low-pitched pure tones (367.0 Hz and 261.6 Hz) and an alternation of two different band-pass noise bursts (3000-3500 Hz and 2000-2500 Hz) were compared. Auditory sequences were presented to participants dichotically via headphones. In the visual cross-attribute condition, two color alternation (red, green) and two orientation alternation (45°clockwise, anticlockwise tilts from the vertical of gratings) were compared. Results showed that the temporal frequency limit for auditory within-attribute binding was around 12 Hz, while it was around 3.5 Hz for auditory cross-attribute binding. The temporal frequency limit for visual cross-attribute binding was around 2.5 Hz, consistent with the previous reports. These findings suggest that the feature-specific mechanism for within-attribute temporal binding is fast, while the feature-invariant mechanism for cross-attribute binding is slow, both in vision and audition.

53.448 **Visual Signals Bias Auditory Targets in Azimuth and Depth**

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Visual bias is a psychophysical phenomenon where an accurately localized irrelevant signal, such as a light, will bias a spatially discrepant target that is localized with less accuracy, such as a sound, when the two stimuli are perceived as unified. Many previous studies have demonstrated visual bias in azimuth, but none have tested directly, or found, this effect in depth. The current study was able to produce over 90% bias in azimuth and somewhat less (83%) bias in depth. Bias can be predicted by the variance of the localization of each unimodal signal in each unimodal signal in each direction in space, as predicted by a maximum likelihood estimate.

53.449 **Amplitude-modulated sounds influence visual inspection of natural scenes**

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We previously demonstrated a linear perceptual relationship between auditory amplitude-modulation (AM) rate and visual spatial frequency using Gabors (Guzman et al., VSS2011). We further demonstrated that this frequency-based auditory-visual association generalizes to the perception of natural scenes (Sherman et al., VSS2011). Participants consistently matched specific auditory AM rates to visual scenes from diverse categories (nature, urban, and indoor). A correlation analysis indicated that this crossmodal association is mediated by the subjective impression of scene density (measured after the auditory-matching task), with a higher/lower density rating associated with a faster/slower AM-rate match. Our new result shows that both the density ratings and AM-rate matches are scale invariant, suggesting that the underlying crossmodal association is between visual coding of object-based density and auditory coding of AM rate. Based on these results, we hypothesized that concurrently presenting a fast (7Hz) AM rate (associated with dense scenes) or a slow (2Hz) AM rate (associated with sparse scenes) might influence the way in which visual attention is allocated to dense or sparse aspects within a scene. We tested this hypothesis by monitoring eye movements while participants examined each scene for a subsequent memory task. The initial five saccades had significantly smaller amplitudes and shorter inter-saccade fixation durations when the faster AM sound was played than when the slower AM sound was played. This suggests that a faster AM sound may operate like a high-pass filter, emphasizing scene details and promoting a local scanning strategy in which objects within a dense region are individuated. In contrast, a slower sound may operate like a low-pass filter, emphasizing larger structures and promoting a global scanning strategy, potentially facilitating perception of gist. In summary, our results suggest that auditory AM rate and object-based visual density are crossmodally associated, and that AM sounds can influence scene inspection through this association.

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53.450 **Adaptation to temporal interval modulates the perception of visual apparent motion**

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In current study, we asked whether and how adaptation to the time interval between two sound beeps would influence the perception of the subsequent visual apparent motion. We presented participant with two successive stimulus frames of a visual Ternus display (Petersik & Rice, 2006; Ternus, 1926), in which each frame had two discs, with the second disc of the first frame and the first disc of the second frame being presented at the same location. Depending on the inter-stimulus interval (ISI) between the two frames, participants could perceive either “element motion” (short ISI) or “group motion”(long ISI). In Experiment 1, participants adapted to either “element motion” (ISI=50 ms) or “group motion”(ISI=200 ms). In Experiment 2, participants adapted to a time interval of 50 or 200 ms through observing two disks flashing at the center of the screen. In Experiment 3, participants adapted to a time interval of 50 or 200 ms through hearing a sequence of two paired sound beeps. After adaptation in each trial, participants were presented with a Ternus probe in which the ISI between the two frames was equal to the transitional threshold of perceiving “element motion” or “group motion”, as determined by a pretest. Results showed that adaptation to the short interval (50 ms) led to more reports of “group motion” for the subsequent Ternus probe. However, no obvious adaptation aftereffect was observed for the long interval (200 ms), except that adaption to the auditory interval gave rise to more “group motion” reports. Overall, these findings suggest that adaptation to a (short) time interval conveyed cross-modally may lead to more expanded perception of the time interval between two visual frames in Ternus display; it is possible that a common neural mechanism underlies the adaptation to the timing of intra- and cross-modal events.

53.451 **Hearing where the eyes see: influence of an uninformative visual cue on sound localisation in adults and children**

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In everyday life, localising a sound source is often necessary for our survival. It is now well known that when visual localisation is good and informative, vision dominates and captures sound (e.g. Alais and Burr, 2004). What is still unclear is whether an uninformative visual signal can bias sound localisation. Optimal use of sensory signals for localisation predicts that an uninformative signal should be ignored. To test this we used an apparatus including 9 speakers positioned at the right side of a computer screen in a semicircle and asked participants to judge which one of two beeps (a standard and a comparison) was closer to the monitor in either a noiseless environment or one with added auditory noise. The comparison beep could be presented either with or without a synchronous flash positioned at the centre of the screen, while the standard beep was always presented alone. We analysed the number of times that the comparison stimulus was perceived as closer to the monitor as a function of beeps’ spatial displacement. For adults, points of subjective equality (PSEs) shifted significantly when the flash was presented, showing that the flash pulled the perceived position of beeps towards the monitor. The addition of auditory noise slightly increased this effect. Preliminary results also indicate that 8-year-old children may be similarly influenced by the flash presentation, but only in the noiseless condition. In the noisy condition, in contrast, their performance is completely disrupted by the flash. These results indicate that uninformative visual information can affect sound localization, resulting in percepts that are not optimal for localising the sound. Auditory noise may differently affect audiovisual integration in 8-year-old children and adults, consistent with recent reports (Barutchu et al, 2010).

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53.452 **Age-related changes in multimodal integration are not due to attentional load**

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Previous research has demonstrated age-related changes in vision and audition. Given these changes, age-related differences in multimodal integration might be expected, but there is relatively little research examining how multimodal integration changes with advancing age. The current study used the sound-induced flash illusion (Shams, Kamitani & Shimojo, 2002), the perception of multiple flashes of a single presented flash when paired with multiple beeps, to examine multimodal integration in younger (mean age 21.4, range 20-23) and older (mean age 71.6, range 66-77) individuals. Twelve younger and twelve older individuals participated in the study. On each trial participants were presented 1-3 flashes of a white disc (127.97 cd/m2), 12° visual angle below fixation presented on a black background (0.06 cd/m2). These flashes were paired with 0-3 beeps (3.5 kHz sine wave tones). Prior to participation in the experiment, their ability to discriminate 1-3 visual flashes and 1-3 auditory beeps was assessed and required to progress further in the study. Participants were asked to report the number of flashes perceived on each trial and to ignore the beeps. In addition, to assess the effects of attentional load, a go/no-go paradigm was used with one block run with a no-go signal on 12% of the trials in the visual domain and one block run with a no-go signal on 12% of the trials in the auditory domain. Results indicate that multimodal integration is retained by older individuals. However, older as compared to younger individuals showed a greater effect of the number of beeps when the difference between the number of beeps and flashes was more disparate. Attentional load did influence the strength of the illusion but did not differ with age. The importance of these findings to aging, attentional load, selectivity and the mechanisms of multimodal integration will be discussed.

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53.453 **The Shifting and Dividing of Attention Between Visual and Auditory Tasks**

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In everyday life we must often shift our attention between tasks that require processing in different sensory modalities, yet the vast majority of experimental work on task switching has focused only on shifting attention between visual tasks. We conducted a set of experiments that required participants to perform a visual task (identifying a shape presented on a computer screen) and an auditory task (identifying a letter presented through headphones). Participants were presented with a pretrial cue instructing them to perform either the visual task, the auditory task, or both tasks on the upcoming trial. We observed significant switch costs for both modalities; that is, trials in which participants were required to switch attention between the visual and auditory tasks yielded longer RTs than trials in which participants performed the same task on consecutive trials. While this pattern is similar to that typically observed in studies requiring participants to switch attention between only visual tasks, we also varied the cue-target interval (CTI) and found that the preparatory cues were used differently in each modality. Switch costs decreased as CTI lengthened in the visual modality but did not do so in the auditory modality, suggesting that visual task cues trigger endogenous, goal-driven processes, while auditory task cues alternatively may trigger an alerting or "warning" effect. Converging evidence for this finding that auditory and visual task cues activate different preparatory processes was also found in the dual task conditions, where participants had to respond to both the auditory and visual targets on the same trial. These results suggest that auditory and visual cues evoke different control processes, a finding that has important implications for understanding how attention is controlled in dynamic, information-rich environments where attention must be shifted and/or divided between multiple tasks that require processing in different sensory modalities.

53.454 **The Effects of Spatial Cues on Age-Related Changes in Audio-Visual Temporal Order Judgments**

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Studies examining the effect of aging on audio-visual temporal order judgments (TOJs) have found mixed results. Virsu et al. (2003) and Setti et al. (2011), for example, reported that the accuracy of TOJs was reduced in older subjects, but previous research in our lab (Fiacconi et al., VSS 2011) found no effect of aging. A possible explanation for the different results concerns the role of spatial cues. Virsu et al. and Setti et al. presented auditory and visual stimuli from different locations, whereas Fiacconi et al. presented stimuli from the same perceived location. Redundant spatial cues, which improve TOJs in younger subjects (Zampini et al., 2003) were available to subjects only in the Virsu et al. and Setti et al. studies. Here we examine if age differences in sensitivity to spatial cues affects age differences in TOJs. In the current experiments, a Gabor pattern and a tone were presented on each trial with various SOAs and subjects determined which stimulus was presented first. In Experiment 1, TOJs were measured in 12 younger (22-30) and 12 older (+70) with the tone presented from speakers positioned, in separate blocks of trials, to the left or right of the visual stimulus. In Experiment 2, TOJs were measured in 17 younger (18-32) and 16 older (70+) with the tone presented from speakers and headphones in separate blocks of trials. Psychometric functions were used to estimate a just noticeable difference (JND) and point of subjective simultaneity (PSS) for each subject. In both experiments, we found no significant effect of age group, spatial cue, or group x cue interaction for either the JND or PSS. The current experiment replicates the findings of Fiacconi et al., and suggests that the difference between studies is not due to age differences in the ability to use redundant spatial cues.

53.455 **Atypical development of temporal perception in ASD is associated with deficits in audiovisual speech integration.**

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While speech perception is thought of as an auditory-first process, it is clear that integrating visual speech has dramatic behavioral impacts. This audiovisual integration of speech is impaired in children with autism. We investigated the role that temporal processing has on audiovisual speech integration. We measured the temporal binding window (TBW), a probabilistic construct reflecting the interval of time within which two sensory signals may be perceptually bound, and related this to the McGurk Effect, a measure of audiovisual speech integration. Three age groups of participants, 6-9, 10-13, and 14-18yo (24 ASD, 40 typical) performed two tasks. To measure the TBW, participants completed an audiovisual simultaneity judgment task where speech tokens were presented at varying stimulus onset asynchronies, 500ms A-V to 500ms V-A. Additionally, participants completed a McGurk task in which they reported their perception to congruent /ba/ and /ga/ utterances and an illusory condition with an auditory /ba/ presented with a visual /ga/. The typical TBW (resembling a normal curve) was wide and symmetrical at the youngest age and narrowed first with the audio-first conditions, producing an asymmetry, followed by a general narrowing of the TBW. Comparatively, ASD individuals showed wider and more symmetrical TBWs, suggesting that these developmental changes failed to occur across age groups. ASD groups also showed a decrease in McGurk perceptions, and importantly, this measure was significantly correlated with the individuals' TBW. The narrower the TBW, the greater the McGurk Effect. Thus, the development of temporal multisensory function was severely impaired in ASD. The ASD group failed to develop an asymmetrical TBW that mirrors the natural statistical relationship between auditory and visual stimuli in the environment. Individuals' TBW widths were significantly correlated with their perceptual fusion of speech stimuli, suggesting this temporal deficit may cascade into deficits of higher-level cognitive processes such as speech perception.

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53.456 **Categorical Distinctions and Image Differences in Cross-modal Working Memory**

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Categorical distinctions between images---for example shape, color, or object type---have been shown to boost accurate image recall over the short term. Do these distinctions offer a similar recall boost for crossmodal associations? In this study, 37 participants detected changes in auditory-visual associations in between-category and within-category trial blocks. In both cases, they observed three sound-image pairs in sequence, then after a blank pause judged whether a test sound-image pair matched one of the earlier items. Only image categories were manipulated; all auditory input involved recognizable animal sounds. Fifteen faces and 15 random polygons were compared for their contributions to crossmodal change detection accuracy.

Half the participants performed category-internal change detection with the face set and distinct-category change detection with random polygons, convex shapes, and drawn objects. The other participants had category-internal trials with random polygons and faces in the distinct-category condition. Although comparisons between gray convex shapes and black concave random polygons might seem more difficult than comparisons between the convex shapes and photographs of faces, crossmodal change detection both within and across categories was better with the random polygons than with the faces, a marginally significant interaction (F(3,2989)=2.5,p=.058). Participants performed two blocks of each experimental condition, and no change detection boost was observed in the later blocks, although reaction time did go down significantly, F(1,2882)=58.09,p<.001. A recognition test was performed approximately 10min after the change detection protocol, after an unrelated lexical decision task. A technical issue reduced this data set to only 14 participants; members of the group that performed within-category change detection with faces showed better recall of particular facial expressions. Both groups struggled to recall the random polygons at better than chance levels. Thus, the polygons' characteristics that conferred greater crossmodal change detection accuracy---compared to associations with faces---did not correspond to better long-term recall.

53.457 Grasping semantic information with and without vision

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When grasping, humans integrate information from different sensory modalities. Even high-level, semantic information can affect the kinematics of the grasping process. We wanted to know whether semantic information alone can specify grasping parameters as, for example, the size of an object. We tested the precision (variability) and the slope of the maximum grip aperture (MGA - maximal opening between index finger and thumb) across different object sizes in a visual, a semantic and a bimodal (visual + semantic) condition. Eighteen subjects grasped bars of different sizes (2-7cm) when seeing a bar (visual condition), hearing a number (2-7) representing the size of the bar without seeing it (semantic condition) or seeing the bar and hearing the size information (bimodal condition). In all conditions, MGA was linearly related to bar size with similar slopes, indicating that verbal information about object size can be used to scale the grip aperture in an efficient manner when vision is not available. Because we used natural viewing conditions, cue integration approaches suggest visual capture, such that visual information should dominate (due to its higher reliability) the semantic information in the bimodal condition. This is what we found (about three times higher variability of the MGA in the semantic condition compared to the visual or bimodal conditions, which did not differ significantly). Based on these results future research can degrade the visual information and measure the degree to which semantic and visual information is integrated in grasping.

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53.458 Auditory input modulates striate visual cortex activity: cortical multisensory integration begins

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Investigations have traditionally focused on activity in the sensory cortices as a function of their respective sensory inputs. However, converging evidence from multisensory research has shown that neural activity in a given sensory region can be modulated by stimulation of other sensory systems. Both electrophysiology and functional imaging support the occurrence of multisensory processing in human sensory cortex (previously described as "unisensory" cortex), based on the latency of multisensory effects and their precise anatomical localization. Still, due to inherent methodological limitations, direct evidence of the precise mechanisms by which multisensory integration occurs within human sensory cortices is lacking. Using intracranial recordings in epileptic patients (n=5) undergoing presurgical evaluation, we investigated the neurophysiological basis of multisensory integration in visual cortex. Subdural electrical brain activity was recorded while patients performed a simple detection task of randomly ordered Auditory alone (A), Visual alone (V) and Audio-Visual stimuli (AV). We then performed time-frequency analysis: first we investigated each condition separately to evaluate responses compared to baseline, then we indexed multisensory integration using both the maximum criterion model (AV vs. V) and the additive model (AV vs. A+V). Our results show that auditory input significantly modulates neuronal activity in visual cortex by resetting the phase of ongoing oscillatory activity. This appears to be a mechanism by which multisensory effects in visual cortex occur when an auditory stimulus is simultaneously presented with a visual stimulus. Here, multisensory effects are characterized by an enhancement of the multisensory response compared to the unisensory visual response. Multisensory responses were also shown to vary with respect to the additive model (that is: multisensory integration effects can be either sub- or super-additive). Our data demonstrate that auditory information commonly reaches a large portion of the striate cortex within the same time range as visual information.

53.459 No Colavita effect: Lack of visual dominance in people with autism spectrum disorder

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Previous research has shown that individuals with autism spectrum disorder (ASD) may perceive the world differently. Superior performance has been demonstrated on perceptual tasks involving detail recognition and visual search; however, deficits have also been demonstrated in tasks such as motion perception and attentional shifting. We investigated whether participants with ASD demonstrate typical visual dominance when presented with an audio-visual event. The current experiments measure speeded detection and discrimination of auditory, visual and audiovisual targets presented as a stream of paired familiar objects and sounds in people with ASD and typically developing controls. We found that all participants were equally able to detect the presence of auditory, visual or bimodal targets. However, when asked to discriminate between the unimodal and bimodal targets the control group demonstrated preferential processing of visual over auditory information with the bimodal stimuli -- the Colavita visual dominance effect. Moreover, participants with ASD, showed no Colavita effect and demonstrated a preference of auditory stimuli compared to visual stimuli or rather, a reverse Colavita effect. This suggests an absence of the typical visual dominance and instead auditory dominance. These results may be due to difficulties associated with integrating information into higher levels of processing. These findings indicate a difference in perceptual processing that may contribute to social communication impairments associated with autism spectrum disorder.

53.460 Cross-modal, positional, and semantic effects in visual extraction of slope

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Extracting slopes from arrays of visual features is relevant to perceiving terrains and interpreting graphs. To understand slope perception in a broader context, we investigated the effects of sounds, position, and semantic priming on a visual search task in which observers searched for a specific slope pattern. We used graphs as the stimuli with the purpose of developing methods to improve graph comprehension. Four bar graphs or scatter plots were simultaneously presented in separate quadrants. The task was to press the space bar as quickly as possible if one of the graphs displayed a specific (positive or negative) slope and to refrain from response otherwise. Concurrently presented ascending (or descending) pitch slowed responses to the positive-slope (or negative-slope) targets, indicating crossmodal interference. Positive slopes were detected faster in the upper-right (than upper-left) quadrant whereas negative slopes were detected faster in the upper-left (than upper-right) quadrant, indicating position dependence. Interestingly, this position dependence is consistent with a standard mental number line with negative values extending to the left and positive values extending to the right, though the position effect occurred only in the upper visual field. Finally, positive slopes were detected faster when the search display was immediately preceded by a briefly flashed word "uphill" than "downhill" and vice versa for detecting a negative slope, indicating a semantic priming effect. This priming effect is unlikely due to reminding observers of the target because the target type was blocked (i.e., observers repeatedly searched for either a positive or negative slope), and the semantic priming only affected the perception of scatter plots (not bar graphs). In summary, perception of visual slope is systematically influenced by auditory signals, placement of graphs, and semantic priming, suggesting that slope perception can be influenced by manipulating underlying auditory-visual associations, spatial position, and semantic associations.

3D perception: Stereopsis, motion, and other cues

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

53.501 Distributed representations for 3D perceptual judgments in human visual cortex

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Responses to binocular disparity are widespread throughout the visual, parietal and ventral cortices, but what features are represented in these different areas? Here we use human fMRI and psychophysics to probe the nature of depth representations in the dorsal and ventral visual hierarchies. We presented participants (N=8) with slanted surfaces depicted in random dots stereograms (±7.5 to 52.5 deg in 15 deg steps) where stimulus size in the image plane was held constant as slant was varied. Psychophysically, we investigated two perceptual properties of these stimuli that varied with base slant: (i) slant discrimination thresholds and (ii) thresholds for the apparent physical size of the surface. We found that sensitivity to slant differences was highest at low base slants. In contrast, sensitivity to changes in surface size was highest at large base slants. Our fMRI measurements aimed to identify visual areas that mediate these perceptual results. During scanning, participants performed a demanding fixation task unrelated to slant or size judgments. We analyzed fMRI data using multi-voxel pattern classification analysis, and characterized decoding performance for neighboring slants in independently-localized regions of interest. We find a dissociable pattern of decoding performance in dorsal and ventral cortical areas. Specifically, sensitivity to neighboring slants was most pronounced for low baseline slants in area V3A and declined as base slant was increased. In contrast, decoding performance in area LO was highest for large slants, and declined as slant was reduced. These different patterns of response matched psychophysical judgments of (i) precise slant and (ii) surface size respectively. Our results suggest perceptually-relevant disparity representations in both the dorsal and ventral visual streams; however, the functional role of these representations appears to differ. Behavioral performance is compatible with accessing dorsal representations to make precise slant judgments, while ventral representations to compute object properties.

Acknowledgement: The Wellcome Trust and a JSPS Postdoctral Fellowships for Research Abroad (H22, 290)

53.502 The interaction between visual mechanisms for 2D and 3D information processing

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In a nature environment, a three-dimensional (3D) object often has a 2D pattern on its surfaces. Thus the visual system often processes 2D and 3D information simultaneously. Here, we showed that the 3D structure of an object affects the perception of 2D patterns and the brain regions for these two types of information inhibit each other. The 2D patterns were symmetric patterns consisted of random dots. The symmetric patterns had one half being the reflection of the other half about a central vertical axis. The 3D structures were created by the disparity between the left and the right eye images. The coherence threshold for symmetry detection was measured (2AFC, PSI staircase) with nine types of 3D structures. Compared with the frontoparallel condition, the threshold increased whenever the two sides of symmetric axis were not coplanar. The thresholds for the slant and the flat conditions were similar. Thus, it is coplanarity, rather than depth per se that was important for the 3D effect. BOLD activation was measured on a Bruker 3T scanner (TR=3s) with a multiple block design (18s per block) in which the stimuli varied either in 3D structure, 2D coherence or both. A ventral occipital area showed greater activation to symmetric patterns than to random dots but the difference decreased when there is a depth contrast in the image. The areas V3A/B showed greater activation to the depth than to the flat conditions. This difference was greater with the random dot 2D patterns than with the symmetric ones. Our results showed that while there is a clear functional segregation between the symmetry area in the ventral stream and the depth area in the dorsal stream, there is much inhibitory interaction between them. Both psychophysics and fMRI results show that 2D and 3D information are not processed independently.

Acknowledgement: NSC 100-2811-H-002-012

53.503 Perceived 3D shape from continuous and static perspective changes

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Studies of structure-from-motion have generally found that perceived depth from motion is not veridical and depends on speed. However, some recent studies have found that observers are capable of accurate metric judgments of shape when there are large changes in perspective (Bingham & Lind, 2008; Lee et al., 2008). We investigated whether continuous motion is required for accurate metric shape judgments from large perspective changes, and whether amount of perspective change modulates the speed dependence of structure-from-motion. Stimuli were views of elliptical cylinders with depth-to-width ratios (0.5-1.5) and with different slants in depth (top face: 60°, 70° or 80°). In the SFM condition, the object was rotated around the normal axis by either ±10° or ±45°. The rotation was sinusoidal with peak speed of either 15°/s, 20°/s or 25°/s. In the static-views condition, the initial and most extreme views were presented as static images, with delay between images of 0.5s, 1.6s, 2.0s, or 2.4s. Observers adjusted the aspect ratio of a 2D ellipse to match the perceived shape of the elliptical face of the 3D object. For both the SFM and static-views conditions, we found that judgments were more accurate with large perspective change. With small perspective change, judgments showed overall underestimation of depth and compression of range. Large perspective change reduced these biases, and in the SFM condition judgments were close to veridical. Accuracy was lower with static-views than SFM, indicating that the improvement was not solely due to the extreme views. We found no effect of rotation speed even with small perspective change, contrary to expectations. We conclude that large perspective change can facilitate structure-from-motion and support near-veridical judgments of 3D shape.

53.504 The role of stereoscopic depth cues in shape constancy

Mercédès Aubin[1,2](mercedes.aubin@umontreal.ca), Sacha Zahabi[1,2], Martin Arguin[1,2]; [1]Université de Montréal, [2]Centre de recherche en neuropsychologie et cognition

The aim of the present study was to determine the role of stereoscopic depth information in the orientation invariance of shape representations. Two experiments using sequential matching tasks were conducted. In both experiments, participants decided whether two stimuli shaped like bent paper clips were the same or different. The stimuli were rotated from 0 to 80 degrees around the vertical axis, and they could be presented without stereopsis, with normal stereopsis or with reversed stereopsis. The presentation mode was within-subject (n=12) in Exp. 1, and between-subjects in Exp. 2 (n=24). There were strong rotation effects in both experiments. In the first session of Exp. 1, the rotation effect was smaller with the stereoscopic presentation than with either the 2D or the reversed stereoscopic presentations. However, these effects were reversed in the second session of the experiment. In Exp. 2, the rotation effect was weaker with the stereoscopic presentation than with either the 2D or the reversed stereoscopic presentations in both sessions. These results indicate that stereoscopic depth cues may contribute to shape constancy. The loss of the benefit of valid stereoscopic information in the second half of Exp. 1 may be due to an adaptation to the inconsistency between the stereoscopic depth cues and the monocular depth cues in the 2D and reversed stereopsis conditions. This may have led participants to switch an initial strategy of trying to derive a 3D global representation of the shape to one of attempting to use 2D pictural cues to perform the task.

53.505 Stereo information benefits view generalization in object recognition

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The aim of this study was to examine the contribution of stereo information to recognition performance of multi-part objects across changes in stimulus viewpoint. A recognition task was performed under either monocular or stereo viewing conditions where participants first learned a set of 12 novel 3D objects from three different viewing angles (Learning Phase) and then discriminated previously learned objects from visually similar distractors (Test Phase). The previously learned objects were presented from either the same viewpoints AS shown in the learning phase or different viewpoints falling between the trained views (Interpolated) or outside of the trained views (Extrapolated). Behavioural measures were obtained from the recognition task to compare performance differences between the monocular and stereo viewing conditions and viewpoint rotations. The accuracy scores revealed an advantage for correctly discriminating previously learned objects viewed from unfamiliar viewing angles when stereo information was available. The results also showed an advantage for recognising interpolated over extrapolated views and the presence of a significant interaction between viewing condition and viewpoint. This suggests that stereo information can modulate viewpoint costs possibly via the integration of stereo-defined depth cues during view interpolation.

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53.506 Humans can use information beyond 2 frames in structure from motion

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Purpose: to determine whether the visual system uses information past 2-frames in determining surface shape from motion information. Using additional frames to (for example) estimate image accelerations would in principle allow richer surface shape representations to be derived. Stimuli and task: simulated ellipsoids were used, defined by dots randomly distributed across the surface. Projection was orthographic. Simulated surface protrusion was varied in six steps; this included a spherical surface, along with surfaces more compressed than a sphere and surfaces more elongated than a sphere. These simulated half-ellipsoids were rotated side to side, five degrees per sweep (object rotation). 2, 4 and 8 frame (per sweep) animations were used. Each sweep lasted 400 ms. Observers then chose which of 8 cross sections most closely matched the cross section of the simulated surface; cross sections 2-7 corresponded to the cross sections of the stimuli shown, while cross sections 1 and 8 were extremes not actually presented. Stimuli were shown through a simulated aperture, spanning 7 degrees. Viewing was monocular. Results: for n=7 observers, there was a highly significant effect of frame number on perceived depth, as indicated by the height of the cross section chosen ($p < .01$). The frame number X stimulus-protrusion interaction was also highly significant ($p < .01$). Paired t-tests on slopes revealed no difference between the 4 frame and the 8 frame conditions (both with positive slopes). But there was a significant difference between the 2-frame condition and the 4-frame condition ($p < .01$), and there was a significant difference between the 2-frame condition and the 8-frame condition ($p < .01$). Conclusions: subjects used information available past 2 frames. This may include image acceleration information; this hypothesis will be explored in subsequent experiments.

53.507 Linear egomotion signals are mostly ignored in the interpretation of the self-generated optic flow

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An observer who approaches a planar surface that rotates about the vertical axis (e.g., a flag hinging on a pole) generates the same Optic Flow (OF) that is produced by a planar surface that rotates about an horizontal axis and it is viewed by a static observer. In spite of this ambiguity, perceived surface orientation by the active observer is usually veridical. This result is consistent with an interpretation of the OF that takes into account egomotion signals (Wexler, 2003). Here, we suggest an alternative interpretation based on a computational model that ignores linear egomotion signals (Domini et al., VSS 2012). An implication of our model is that perceived orientation should flip by 90° whenever the OF undergoes a translational motion in a direction orthogonal to the surface axis of rotation. OF translational motion is always present when an observer moves towards or away from a stimulus display, due to the natural rotations and translations of the head. In the present experiments, we tested our alternative explanation by asking observers to judge surface orientation in three conditions: (1) when a random-dot planar surface rotated about a stationary axis, (2) when the axis of rotation was tethered to a coordinate system centered on the observer's head, so as to eliminate the translational components of the OF, and (3) when a translational component was added to the OF produced in (2). The results are consistent with the predictions of our model. Perceived surface orientation (i) was veridical in (1), (ii) was ambiguous in (2), and (iii) underwent a 90° flip with respect to veridical in (3). A similar pattern of results was found when the same OFs, generated by the observer's movements, were replayed to a static observer.

53.508 The effects of age upon the perception of 3-D shape from motion

J. Farley Norman[1](Farley.Norman@wku.edu), Jacob Cheeseman[1], Jessica Pyles[1], Hideko Norman[1]; [1]Western Kentucky University

Prior research (e.g., Andersen & Atchley, 1995; Norman, Dawson, & Butler, 2000; Norman, Clayton, Shular, & Thompson, 2004; Norman, Bartholomew, & Burton, 2008) has examined the detectability and discriminability of curved 3-D surfaces defined by optical motion. These studies have demonstrated that the performance of older adults (60 to 85 years of age) is frequently worse than that exhibited by younger adults (20 to 30 years of age). Nothing is presently known, however, about the perceptual capabilities of middle-aged adults. One goal of the present study was to study the decline in the ability to perceive 3-D shape from motion in more detail. For example, does the ability to perceive 3-D shape from motion decline continuously throughout the lifespan, or does it remain high throughout middle adulthood and only deteriorate at later ages? In the current study, 30 adults (ages ranged from 19 to 84 years) discriminated between three smoothly curved surfaces. The surfaces all had sinusoidal depth modulations, where the resulting peaks and troughs formed concentric circles, were radially-oriented, or were arranged like an "egg-crate" (depth = sin(x) * sin(y)). The visibility of the surfaces was degraded to varying degrees by limiting the lifetimes of the surfaces' constituent points. Psychometric functions relating discrimination accuracy to surface point lifetime (number of successive views in the apparent motion sequence during which individual surface points were presented) were determined for each observer.Hidden formatting deleted. Delete this text! yes"> The point lifetime thresholds (i.e., the point lifetime needed for 66.7 percent discrimination performance) were 4.0 views, 4.9 views, and 9.0 views for younger, middle-aged, and older observers, respectively. Our results reveal that the ability to perceive 3-D shape from motion persists throughout middle adulthood and only begins to decline at later ages (e.g., 65 years of age or older).

53.509 The role of symmetry in 3D shape discrimination across changes in viewpoint

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Previous research has suggests that the symmetry of a 3D object facilitates shape constancy across changes in viewpoint (Vetter et al., 1994; Pizlo & Stevenson, 1999; Saunders & Lee, 2011). The aim of this study is to show that symmetry only facilitates shape constancy by cueing the direction and magnitude of the change in viewpoint. Discrimination performance is equivalent when similar cuing is provided for asymmetrical shapes. Symmetric and asymmetric globally convex 3D shapes were generated to have similar complexities by phase scrambling their spherical harmonics while retaining the frequency and amplitude of the shape properties. The shapes were shaded by a diffused point light source. The same symmetrical and asymmetrical shapes were rendered with and without surface contours in addition to the shading. The versions of the shapes with surface contours were circumscribed with a single contour. For symmetrical shapes, the contour followed the plane of symmetry. Shape pairs were presented sequentially in a same/different shape discrimination task with monocular viewing. The second shape presented was rotated about its central vertical axis by a maximum of ±60°. Observers' ability to discriminate shape was negatively correlated with the magnitude of rotation in all conditions. There

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was an interaction between the shape symmetry and whether or not surface contours were present. Observers performed better when shapes without contours were symmetrical compared to asymmetrical. The addition of surface contours to asymmetrical shapes increased the performance to match that of symmetrical shapes. These results suggest that both symmetry and surface contours are used as diagnostic features to identify the magnitude of rotation. Once the magnitude of rotation has been determined, symmetrical shapes are no easier to discriminate between than asymmetrical shapes.

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53.510 **Reduced depth illusions in schizophrenia: The state of the illness matters but the kind of object may not**

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Purpose. People with schizophrenia are less susceptible to illusions in which pseudoscopically-presented concave objects appear as convex. Here, we ask: Does this reduced illusion also occur with physical objects? If so, does it depend either on the state of the illness or on abnormal processing of specific visual attributes? Method. To address these questions, 19 healthy controls and 19 persons with schizophrenia made convexity judgments about 5 physical objects. Two objects were concave scenes ("reverspectives"); two were concave faces; and one was a convex face (catch stimulus). A reverspective and a concave face were painted with life-like texture; the remaining objects were uniformly colored. All five objects were viewed twice—once monocularly with the subject moving left-right (parallel to the objects, to create motion parallax) and once stereoscopically with the subject stationary. For each of the ten viewings, subjects were probed every 12 seconds for 2 minutes on whether the object appeared convex or concave. Results. The two subject groups were equally adept at identifying the catch stimulus as convex ($p>.25$). For concave objects, patients gave more accurate (veridical) responses than controls ($p<.05$). This group difference increased with illness severity ($p=.02$), as measured by the number of months since the last hospitalization (ranging from <3 to >24 months). Across all subjects, the illusion weakened when stereoscopic cues were present ($p<.001$) or when texture cues were absent ($p<.001$). The group difference did not depend on texture, object-type or viewing condition ($ps>.24$). Conclusions. We conclude that 1) physically concave objects produce fewer depth illusions in schizophrenia; 2) veridical perception increases with illness severity; and 3) the group difference is constant across different object types and viewing conditions. This last conclusion implies that reduced illusions in schizophrenia may not be stimulus- or attribute-specific but instead may owe to a weakened convexity prior.

53.511 **Compression of motor space expands perceptual spaces**

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Seeing the arm in a different position than the actual, induces visuo-motor recalibration that rapidly modifies motor commands when reaching towards objects. Here we ask whether visuo-motor training affects not only motor, but also perceptual aspects both in visual and somatosensory domains. Recently, we showed that judgments about the relative depth of 3D objects, measured with a manual depth estimation task, increased after a visuo-motor training that compressed the motor space in depth (Volcic et al., VSS 2011). Although it is considered that the manual estimation task reflects perceptual judgments, it still comprises motor components. In Experiment 1, to obtain a purely perceptual measure, we asked observers to adjust the width of a virtual object in order to match it to its depth extent. Different disparity-defined objects were positioned at several viewing distances with consistent vergence and accommodative cues. The adjustment task was performed before and after a visuo-motor training in which participants made reach-to-point movements in depth towards a target. Visuo-motor training was of two kinds: vision and proprioception were either congruent or incongruent. When incongruent, the visual feedback of the index finger was displaced farther in depth. The perceived relative depth consistently increased after the incongruent, but not after the congruent visuo-motor training, emphasizing the relationship between motor and visual perceptual processes. In Experiment 2, we studied the effects of visuo-motor training on somatosensory perceptual processes by measuring two-point tactile discrimination thresholds on the exposed arm. We found that tactile spatial resolution was improved following incongruent visuo-motor training. Taken together, these results suggest that our visual and somatosensory perceptual experiences strongly depend on the sensorimotor contingencies that are established through the interaction with the surrounding world.

53.512 **Holistic representations of impossible objects**

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Holistic representations emphasize the global structure of objects rather than their local elements. The current study focused on impossible objects, 2D shapes that seem to represent objects that could not exist in real 3D space. It has been suggested that, unlike possible objects, impossible objects cannot be represented in a holistic manner because they lack a valid structural description. Here, we used behavioral repetition priming and fMRI adaptation to further explore this account. In the behavioral experiment, comparable repetition priming effects were found for possible and impossible objects, suggesting that these object classes are represented in a similar manner. Additionally, the priming effects were not correlated with the number of local structural violations that elicited the "impossibility" of these objects, suggesting a global processing style for impossible objects. In the imaging experiment, we used fMRI adaptation to compare the neural representations subserving the perception of possible and impossible objects. Importantly, equivalent adaptation effects were observed for possible and impossible objects in high order, object selective visual cortex, suggesting that similar representations mediate the perception of these two object classes. Taken together, these findings suggest that the perception of possible and impossible objects is mediated by overlapping cognitive and neural mechanisms. This study further stresses the centrality of holistic processing in human visual perception and suggests that this processing style is applied even on atypical stimuli such as impossible objects.

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Object recognition: Features and parts

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

53.513 **Adapting to an incomplete curve generates the same curvature aftereffect as a complete curve**

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We showed that curve adaptation can propagate along the visual hierarchy to influence high-level facial expression judgment, and furthermore this effect is highly local (Xu et al., 2008). The question remains whether adapting to an incomplete curve generates the same aftereffect as adapting to a complete curve. In the current study, the adapting stimuli are a concave curve, and a set of 8 bisected concave curves with a variable central gap, displayed in separate conditions. The test stimuli are a set of curves varying from convex to concave. In each trial, observers viewed the adapting curve for 4 s, and after a 500 ms inter-stimulus interval viewed a test curve for 100 ms. Observers judged the curvature of the test curve (convex or concave) via a key press. A baseline condition without adaptation was also conducted. We measured the curvature aftereffects for all the adaptors as shifts of the psychometric curves from the baseline condition. We found that the curvature aftereffect produced by the complete-curve adaptor is the largest among all the adaptors ($n = 5$, $p = .014$), as expected. Interestingly, we found a significant curvature aftereffect ($p = .038$) when the gap of the incomplete curve adaptor is small (1/10 of the complete-curve length). The aftereffect remains significant as the gap increases to half the length of the complete curve ($p = .013$). When the gap increases further, the aftereffect gradually decreases to zero. This result suggests that we do not need the entire curve to generate curvature aftereffect. The observed aftereffect for incomplete-curve adaptation may have two possible explanations: 1)

adaptation to the two ends of the incomplete curve, indicating the low-level root of visual adaptation; 2) perceptual filling-in for the missing part, indicating the top-down influence along the cortical hierarchy.

53.514 **Two perceptual anomalies explained by a statistically optimal model**

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Interpreting the visual world often requires us to judge whether two stimuli are the same, or different. The computational mechanisms by which we assess visual similarity and difference, however, remain poorly understood. One puzzle is the well-replicated finding that human observers are faster at judging two multidimensional visual stimuli to be the same than different (the 'fast-same' effect). This is curious, because visual similarity can only be confirmed after an exhaustive search over all relevant features or dimensions. Moreover, although participants are slower to judge dissimilarity when done on only one dimension compared to two, this effect reverses when the similarity is defined disjunctively rather than conjunctively – the 'criterion effect'. A unified account of perceptual comparison that can accommodate these phenomena has remained elusive for many years. Here, we show that an ideal observer model in which stimulus features are processed simultaneously can account for both effects. The model iteratively estimates posterior belief about each possible identity of a comparison stimulus that is being compared to a previously-viewed standard, using Bayes' rule. The total log posterior odds for 'same' vs 'different' identities is accumulated to a threshold value, at which point a choice is triggered. Comparing simulated cycles-to-bound with human decision latencies, the model accurately predicts the 'fast-same' and 'criterion' effects for visual comparison tasks involving both discrete and continuously-varying feature information. The only free parameter in the model reflects the observers' prior belief that standard and comparison will match, and variation in this parameter alone is sufficient to explain the complex patterns of data observed in the conjunctive and disjunctive versions of the task. These findings suggest that perceived similarity reflects the geometry of an internal, multidimensional space of representations, and that judgments of sameness and difference can be accommodated under a single-process, statistically optimal framework.

53.515 **The markedly greater sensitivity to nonaccidental vs. metric shape properties is not reflected in HMAX calculation of shape similarity**

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Nonaccidental properties (NAPs) are image properties that are invariant over orientation in depth and are distinguished from metric properties (MPs) that can change continuously with variations over depth orientation. To a large extent the presence of NAP differences are what allow facile recognition of objects at novel viewpoints. Two match-to-sample experiments with 2D or 3D appearing geons assessed sensitivity to NAP vs. MP differences. A matching geon was always identical to the sample and the distractor differed from the matching geon in either a NAP or an MP on a single generalized cone dimension. For example, if the sample was a cylinder with a slightly curved axis, the NAP distractor would have a straight axis and the MP distractor would have an axis of greater curvature than the sample. Critically, the NAP and MP differences were scaled so that the MP differences were slightly greater according to pixel energy and Gabor wavelet measures of dissimilarity. Exp. 1 used a staircase procedure to determine the threshold presentation time required to achieve 75% accuracy. Exp. 2 used a constant, brief display presentation time with reaction times and error rates as dependent measures. Both experiments revealed markedly greater sensitivity to NAP over MP differences (e.g., 2X the NAP exposure duration required for MPs to reach 75% accuracy in Exp. 1), and this was generally true for the individual dimensions. The NAP advantage was not reflected in the similarity computations of the C2 stage of HMAX, a widely cited model of later ventral stream processing. The C2 output depicted greater dissimilarity to MPs, in contrast with the psychophysical results.

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53.516 **Perceptual prevalence of first-order information in letter identification showed using visual chimeras**

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Two parallel visual mechanisms have been proposed for spatial processing: a linear one devoted to processing luminance and the detection of fine-grain details (first-order mechanism), and an independent linear-nonlinear-linear mechanism devoted to processing the modulation of contrast, frequency, or orientation (second-order mechanism). The perceptual contribution of each mechanism in the identification of natural images can be shown by means of AM-PM visual chimeras (Sierra-Vázquez & Serrano-Pedraza, 2011, Perception, 40). A visual chimera is a synthetic image that has the first-order structure (phase-modulated or PM carrier) of one natural image and the local contrast or envelope (amplitude-modulated or AM component) of another image in a particular spatial-frequency band. In order to synthesize it, the PM carrier and the envelope were computed using the Riesz transform and the associated monogenic signal (the counterpart of the analytic signal in which the Riesz transform replaces the Hilbert transform). In this work we used a letter identification task. We used two visual chimeras as stimuli: a chimera with the envelope of the letter B and the PM carrier of the letter S, and vice versa. We manipulated the PM carrier, changing its contrast from 0.01 to 0.64 and masking it with broadband white noise of fixed energy. Psychometric functions and reaction times (RTs) from the identification task showed that at high PM-carrier contrast, the first-order information dominated and the subject identified the letter from which the PM carrier was taken, with RTs of about 400 msec. However, when the PM-carrier contrast was low, the first-order structure was absolutely masked and the subjects identified the letter from the information present in the envelope, with slower RTs (550 msec). Our results show that when first- and second-order information is available, our visual system shows a consistent perceptual prevalence of the fine-structure information in letter identification.

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53.517 **The integration of parts during visual completion is inefficient**

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More often than not, objects that we see are partially hidden by other objects. As such, the images that fall upon our retinae are typically composed of object fragments separated by regions of occlusion rather than complete figures. Nevertheless, we perceive the world as being populated by cohesive forms rather than collections of independent parts. These image fragments must therefore be bound together in order to be perceived as wholes, a process known as 'visual completion'. But how well do we integrate the parts of objects when forming perceptual wholes? Conventional wisdom suggests that our visual system should be exceptionally efficient at such a process--that a perceptually organized whole should be processed in a manner that is superior to what one would simply predict from performance with each individual part shown in isolation. We tested this idea by using a psychophysical summation-at-threshold technique (Nandy & Tjan, 2008). Specifically, we measured an observer's contrast sensitivity S for discriminating perceptually complete figures as well as each of their constituent parts shown in isolation. From this, we computed an integration index Φ, where $\Phi = S2whole / \Sigma ni=1\ S2part\ i$ and n equals the number of individual parts that make up a whole figure. $\Phi = 1$ indicates the whole is processed in a manner that is predicted by performance with its individual parts, $\Phi > 1$ indicates the whole is processed more efficiently than would be predicted by performance with its individual parts, and $\Phi < 1$ indicates the whole is processed less efficiently than would be predicted by performance with its individual parts. We find Φ to be significantly less than 1 across a variety of tasks involving the discrimination of perceptually complete figures. That is, we find the process of combining parts together to form perceptually complete wholes to be surprisingly inefficient.

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53.518 **Recognizing real-world objects: the role of familiarity, context and features**

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The current study assessed the contribution and interaction of contextual, featural and familiarity-based factors in the recognition of real-world, photographed objects.Participants sequentially resolved degraded photographs of household objects while attempting to identify them; the threshold of degradation at which each object could be correctly identified was taken as a measure of recognition performance. Participants included 'experts' who were highly familiar with the environments in which the pictures were taken and 'non-experts' who were unfamiliar with them. We also included three contextual conditions: 1) participants briefly viewed the contextual scene, as well as the target object's location in the scene, before performing the recognition task 2) participants viewed the contextual scene only, without position information and 3) participants saw no visual contextual information. Across all conditions, we considered the impact of several contextual factors including the consistency of the object within the context and whether the object was moveable or non-moveable within the scene. In addition, we considered factors pertaining to the objects themselves including whether each object was a typical example of its category, the complexity of its shape, and the resolution of the original image of the object. Some main findings include that experts performed better than non-experts but only in the contextual conditions. Experts' performance benefited both from contextual and positional information for all objects and was not affected by the consistency of the object within the scene. Non-experts' performance benefited from consistency; furthermore, the facilitation of context for novices was modulated by both the consistency and movability of the objects. Typicality affected non-expert performance only, while shape complexity affected both experts and non-experts performance. These results demonstrate that both experts and non-experts utilize context for visual recognition, with experts relying on detailed representations of familiar scenes and non-experts relying on schema-level representations.

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53.519 **The "Gist" of Visual Processing**

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Visual information in humans is processed by two separate visual pathways. One is the magnocellular visual pathway (M-pathway), which carries high temporal frequency information but low spatial frequency information. The other is the parvocellular visual pathway (P-pathway), which carries low temporal information but high spatial information. Moshe Bar and colleagues (2007) presented participants with high and low spatial frequency images and found that participants made faster and more accurate categorization responses to the low spatial frequency images. They hypothesized this was due to low spatial frequency "gist" information being rapidly carried by the M-pathway that helps support rapid object perception. In order to directly test the involvement of the M-pathway in "gist" processing, we used red diffuse light, which selectively inhibits the M-pathway (e.g., West, Anderson, & Pratt, 2010) but leaves the P-pathway activity untouched. In our experiment, we presented participants with low and high spatial frequency images under either red or green (control condition) diffuse light and asked them to judge whether the object was larger or smaller than a shoebox. We replicated the original finding of an advantage in categorizing low spatial frequency images, and found this advantage existed under both green and red light conditions. Thus, it does not appear "gist" processing is uniquely carried by the M-pathway. In addition, we found that responses were much faster overall with red diffuse light than green diffuse light. Given that inhibiting one pathway can bias activity in the other pathway ((Yeshurun, 2004), the faster responses under red diffuse light may reflect a processing advantage is the object perception P-stream. In this case, processing with a single visual stream may provide faster responses than when two streams are working in parallel.

Acknowledgement: NSERC

53.520 **Dynamic Visual Representations of Scenes and Objects: The Forest to the Tree**

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Natural visual experience is seamless; we can quickly and effortlessly extract across stimulus categories, such as objects and scenes, while adapting to differences in physical input and task demands. For instance, when walking through the woods one can choose to inspect the richly textured bark of a tree, take a step back and perceive a single redwood, or step back further to take in the entire forest. Much work has focused on the cortically distinct representations of scenes, objects, and faces; naturalistic switches have been largely unstudied, despite that most of our waking hours are spent changing our gaze direction (panning) and distance from (zooming) various objects, people, scenes, and textures. We created a novel stimulus set of 16-second "movies" (constructed by cropping 240 frames from a high-resolution image) that zoom and pan to gradually change from predominantly object to predominantly scene. By playing these movies backwards and forwards, we intend to characterize how dynamic inter-category transitions influence overt attention and categorization judgments while holding constant low-level visual features. To determine the influence of one's experience with a stimulus on its subsequent interpretation, we asked observers to judge whether the label 'object' or 'scene' best describes each movie along its time course. Each trial presented a movie twice: observers first viewed it freely, then were given semantic labels for judging the transition (e.g., 'city to car'). They pressed a key to indicate when they first perceived the image to be predominantly 'car' as they viewed the movie again. Overall, both scene-to-object and object-to-scene iterations were reported as predominantly scene. Notably, we found an effect of anchoring on the first-presented stimulus: observers categorized the movie as an object about 3.12s longer if the movie began with an object. This suggests a marked effect of perceptual hysteresis for the object-scene category judgment.

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53.521 **Text adaptation: Aftereffects for word-identity and handwriting-style, and the effect of the orthogonal variable.**

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Background: High-level face aftereffects have been used to explore face representations. Written words are another high-level stimuli, which activate a similar network on fMRI as faces, only left dominant rather than right. Adaptation for word stimuli has been less investigated: if word aftereffects were found, this might prove useful for exploring the nature of word representations as well. Objective: We used a perceptual-bias paradigm to investigate aftereffects for two orthogonal properties of text, word identity and handwriting style, and see if such aftereffects are affected by variations in the orthogonal dimension. Methods: Two 4-letter and two 5-letter words were selected from the MRC psycholinguistic database, matched for familiarity, imagability and concreteness. Each set of words was handwritten by two people. For word-identity adaptation, test images were created by morphing between the two words of the same length in the same handwriting. Trials showed an unmorphed word for 5 seconds, followed by a brief view of an ambiguous test, after which subjects indicated which word the test most resembled. In one block, the adaptor and test had the same handwriting, differed in the second. For handwriting-style adaptation, morphs were between two handwritings for the same word. Trials showed an unmorphed word for 5 seconds, followed by an ambiguous test, subjects indicated which handwriting the test most resembled. In one block, the adaptor and test shared the same word; differed in the second. Results: We found a word-identity aftereffect but no handwriting aftereffect. The word-identity aftereffect was equally strong when the handwriting differed between adapting and test stimuli, indicating complete transfer of word-identity adaptation across handwriting style. Conclusion: Similar to face aftereffects, adaptation for word-identity can be shown. Complete transfer across handwriting style both supports a high-level origin of this aftereffect and suggests that word representations are independent of the carrier style.

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53.522 **Contour change detection in the periphery: threshold as a function of temporal interval**

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We investigate the ability of human observers to detect small rotational changes in elements of a contour as a function of temporal separation and relative position. A contour, made up of seven discrete Gabor elements (SD of 0.16 deg and a centre-to-centre separation of 2 deg visual angle) constructed via co-circular rotation, was presented at different eccentricities in either hemifield (2, 4, and 6 deg). A subsequent stimulus, presented in either hemifield, was either identical to the first, or differed in shape: each element underwent a small rotation, but adhered to the co-circular construction rule. A forced-choice procedure with an adaptive staircase was used to find the minimum rotation threshold for accurate discernment of a change in shape of the contour. We found remarkably consistent performance over a range of inter-stimulus intervals (ISI) from 500 ms to 16 ms (a single frame at 60 Hz). Reduction of the ISI to 0 ms, when presentation of both stimuli was in the same hemifield and eccentricity, resulted in a dramatic drop in threshold, most likely due to the impact of a relative motion cue that is blocked with even a 16 ms ISI. The relative motion cue was also found to be sensitive to small horizontal jitter. We discuss our findings in the context of the change-blindness and contour-integration literatures.

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53.523 **The flash-lag effect for two features changing simultaneously: a test of alternative hypotheses**

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In the flash-lag effect, a feature of a continuously-changing stimulus is perceived to be ahead along its feature continuum compared to the same feature of a pulsed stimulus (Sheth et al., 2000). This “lead time” is different for color and orientation; when both features change continuously, observers report a combination of features at the time of the pulse that was never actually presented (Kang & Shevell, JOSA A in press). Two hypotheses have been proposed to explain the flash-lag effect. The extrapolation hypothesis assumes that the visual system corrects for neural latencies by extrapolating the trajectory of the continuously-changing stimulus into the future. The postdiction hypothesis assumes that the pulse sets the start of a temporal integration window for the continuously-changing stimulus. These hypotheses were tested by changing features either (i) only before the pulse (PRE condition, to test extrapolation) or (ii) only after the pulse (POST condition, to test postdiction). A circular window (diameter 2.6deg) with a 1.3cpd square-wave grating appeared on one side of fixation. In the PRE condition, both the color and orientation of the grating changed continuously for 720msec before a pulsed stimulus appeared on the other side of fixation. During the 80msec pulse, the color and orientation of the pulsed and continuously-changing stimulus were the same. Following the pulse, the features of the continuously-changing stimulus did not change. The POST condition was the opposite: the continuously-changing stimulus changed its features for 720msec only after the pulse. Observers compared the pulsed to the continuously-changing stimulus in both color and orientation. In the POST [PRE] condition, the lead time was 182msec [53msec] for color and 63msec [-1msec] for orientation. The lead-time differences primarily support the postdiction hypothesis, though the short lead time for color in the PRE condition suggests the integration window begins prior to pulse onset.

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53.524 **Key object feature dimensions modulate texture filling-in**

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Filling-in is a perceptual phenomenon in which visual attributes such as color, brightness, texture or motion are replaced by those in a neighboring region of the visual field. Although many studies have explored lower-order filling-in in early areas of visual cortex (Spillman), the mechanisms underlying higher-order filling-in remain unknown. Previously, we showed that neighboring columnar-scale clusters in macaque inferior temporal cortex encode opposing features or ‘key dimensions’ (Lin et al. 2009 SFN) and that these key dimensions are measurable in human LOC (Yeh et al. 2010 SFN). Here, we asked whether the macaque key dimensions predict the speed of texture filling-in in humans. We show that textures with matched key dimensions fill in significantly faster than textures with different key dimensions. This difference in filling-in latency was not due to low-level features or object size. We suggest that texture filling-in is modulated by features encoded in higher visual cortex, and that such feature dimensions are consistent across monkeys and humans. These results strengthen the case for common representations and mechanisms underlying form vision in primates.

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53.525 **Feature combination produces stimulus quality-dependent changes in object inversion effects**

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The inversion effect is often considered a hallmark of “holistic” processing with face objects. Because non-face objects show smaller inversion effects than faces, they are thought to be recognized using feature-based processes, not “holistic”. Previously, we showed that one of the keys to obtaining large inversion effects (or “holistic” processing) is the strategic combination of object features. Here, we extend this line of research by investigating the role of stimulus quality on these combinatorial effects. In Exp 1, four sets of novel objects and four sets of face objects were created by manipulating specific top and bottom features. Top diagnostic sets varied only in the top features, bottom diagnostic sets varied only in the bottom features. Conjunction sets varied across both top and bottom features, with OR conjunctions allowing the use of either the top or the bottom, and with AND conjunctions requiring the use of both the top and the bottom. Results showed large inversion effects for both face and non-face objects in the AND condition, but only for face objects in the OR condition. There were no inversion effects in diagnostic conditions. These results are consistent with our previous conclusion that strategic feature combination is related to the size of object inversion effects. In Exp 2, stimuli from the novel OR and AND conditions were presented at three different levels of stimulus quality (signal-to-noise ratio). Results showed that lower stimulus quality produced larger inversion effects, but only in the AND condition. The results suggest that the feature combination process that contributes to inversion effects is recruited more when stimuli are degraded. The results are discussed in relation to the principle of inverse effectiveness used in the study of sensory integration.

53.526 **A gaze contingent object recognition paradigm for testing the advantage of viewing specific regions of novel objects.**

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A recent eye tracking study by Leek et al. (in press, Journal of Vision) has provided evidence that the regions of an object that participants fixate during an object recognition task is driven by underlying shape properties and is remarkably consistent across viewpoint. While eye tracking is a powerful tool to determine the areas participants tend to view, it does not provide direct evidence of the relative importance of the areas that are fixated during the viewing of an object compared with those areas that are not fixated. Here we present a new gaze contingent object recognition paradigm that is designed to investigate the relative importance of those areas that are fixated in object recognition tasks. In this task, participant’s eye movements were recorded as they viewed a series of novel 3D objects that they were informed they would later be asked to recognise. The eye movement data from this viewing phase was analysed and the regions that the participants fixated for each object was determined. The regions the participant viewed during this phase were considered ‘critical’ regions. The participants then performed a gaze contingent object recognition task where the participants received a brief exposure of either a previously seen ‘target’, or a previously unseen ‘non-target’ object. Critically, during the recognition task, the target stimuli were presented at fixation in such a way that the participant’s gaze fell upon either (a) a previously fixated ‘critical’ region, or (b) a ‘non-critical’ region which could be anywhere in the object, but not within the area of a critical region. The results show that participant’s performance is superior when they are shown a critical region compared with a non-critical region providing converging evidence of the selectivity of fixated regions in object recognition.

53.527 **Greater modulation of LO responses to changes in nonaccidental than metric relations between simple shapes.**

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Variation in the relations between objects is made explicit, often uniquely, at the same cortical locus—the lateral occipital cortex (LO)--where object shape is made explicit (Kim & Biederman, 2011; Kim, Biederman & Juan, 2011). Given the co-localization of shape and relations, do variations in the relations between shapes exhibit the greater sensitivity to viewpoint invariant (or nonaccidental) properties (NAPs) than metric properties (MPs) that are evident when discriminating individual shapes? In an adaptive staircase design, we compared the sensitivity for detecting a NAP relational change between two shapes, e.g., from a pyramid centered above a brick to the pyramid slightly off centered over the brick, and an MP change, e.g., where a slightly misaligned pyramid is varied to a pyramid further misaligned over the brick. Detecting the MP changes required more than double the stimulus display time compared to detecting the NAP changes. This held true even though the NAP and MP variations were matched in retinal and V1 physical similarities (Kim, Biederman & Amir, 2011). In two fMRI experiments, we show that the NAP relational changes consistently produce greater BOLD modulation than MP changes in LO, implicating LO as the potential neural locus for where the greater detectability of NAPs over MPs is made explicit. None of the other regions tested (V1-V4, posterior fusiform gyrus, and middle temporal cortex) showed this pattern of results. The similarity scaling of our stimuli with HMAX, a model of ventral pathway cell tuning (Mutch & Lowe, 2008), did not consistently yield greater dissimilarity values for the NAP variations that could have accounted for the greater NAP advantage witnessed in the behavioral performance and LO responses. There is thus a need for further development of this model to reflect the greater sensitivity to NAPs which are critical for view invariant object recognition.

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53.528 **The effects of age, luminance and pupil size on visual ERPs.**

Magdalena Bieniek[1](magdalenab@psy.gla.ac.uk), Luisa Frei[1], Guillaume Rousselet[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow

Visual event-related potentials (ERPs) to objects tend to increase in latency with age. It is unclear how optical and neural factors contribute to this delay, and to the considerable amount of within-age group variability (Rousselet et al., Frontiers in Psychology 2010, 1:19). For instance, age-related slowdown of visual processing might be due to senile miosis - a decrease in pupil size with age that reduces retinal illuminance. To tease apart the contribution of senile miosis and luminance to age-related changes in visual ERPs, we recorded EEG from 55 participants, aged 18-79, in two sessions each. Images of faces and phase scrambled noise textures were presented in 9 blocks of 150 trials each. We used neutral density filters that reduced the original screen luminance in block 1 (60.8cd/m2) by half in each subsequent block, to arrive at 0.59 cd/m2 in block 8. Block 9 was a repeat of block 1. We analysed the time course of face-texture contrasts in every subject using bootstrap statistics. Linear regression on the preliminary data from 26 subjects (10 young: 18-25 years-old, 8 middle-age: 32-59 and 8 older: 60-79) showed a significant age-related delay in ERP integration time at all luminance levels (average slope = 1 ms / year). However, none of these delays remained significant after accounting for pupil size. To investigate if there is a causal relationship between pupil size and processing speed across age groups, we are undertaking two more studies: one study using 1 to 6 mm pinholes to directly manipulate pupil size in young subjects, another study using simultaneous EEG and ERG (electro-retinogram) recordings that will allow us to disentangle cortical and retinal contributions to age-related ERP delays.

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53.529 **The Artist's visual span: better performance through smaller windows.**

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Visual artists typically have years of intensive training in observing and reproducing visual scenes. Clearly, they develop advanced motor skills, but does their training also affect their visual perception? In previous studies, two perceptual factors have been examined that may be acquired with extensive practice and that may contribute to the better accuracy of artists' drawings compared to those of non-artists: 1. access to the proximal (retinal) image unaltered by the size, color, and lightness constancies that must be undone to reproduce a scene and 2. more extensive integration of scene elements (larger visual chunks). In a previous study, we found that artists' skill in reproduction was not related to more veridical perception: artists were as affected by visual constancies as non-artists (Perdreau & Cavanagh, 2011). Here we test whether artists may have an advantage in encoding complex scenes — just as expert chess players show advantages in encoding complex arrangements of chess pieces. If this is the case, artists (specifically those with skills in figurative arts) may be able to extract and integrate more information at each fixation of a scene. We used a gaze-contingent moving window to control the amount of information available surrounding the fovea (with the periphery blanked out). Line drawings of possible and impossible objects (like the Penrose triangle) were displayed and the subjects were asked to scan the objects and report, as quickly as possible, whether the object was structurally possible or not. Our results found a negative correlation between drawing skill and smallest window size at which the task could be performed, suggesting that artists can integrate complex scene structures from smaller image samples than the less skilled.

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Scene perception: Spatiotemporal factors

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

53.530 **What's "up" in boundary extension? Brief rotated views are remembered as more expansive**

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Observers remember seeing beyond the edges of a view (boundary extension: BE). A multisource model suggests that visual scenes are rapidly set within a spatial framework; at test observers misattribute top-down-generated expectations to having been seen (Intraub 2011). This misattribution (BE) is associated with activity in scene-selective brain areas (PPA & RSC: Park et al., 2007). In other research, inverted scenes yielded decreased PPA activity compared to upright (Epstein et al, 2005). Might BE similarly decrease for inverted scenes under time pressure? If the view must be mentally rotated to fit an "upright" spatial framework, this could disrupt development of BE in a speeded task. In contrast, if view-taking is fast and flexible, disorientation may have no effect. Observers were assigned to one stimulus-duration condition: 125, 250 or 375 ms (N=72 in each). On each of 36 trials a square photo-image was presented for the designated duration, interrupted by a 250-ms mask, and then immediately reappeared to be rated as the same, much closer or much farther (5-pt scale) than the brief view. Across trials, upright, sideways and inverted photos were intermixed. Significant BE occurred in all but the upright-125-ms condition. A 3 (Stimulus Durations) x 3 (Orientation) Mixed ANOVA on mean boundary ratings revealed greater BE as duration lengthened, $F(2,213)=3.877$, $p<.025$, and greater BE for disoriented views, $F(2, 426)=8.089$, $p<.001$ (supported also by contrasts): no interaction. Increased BE with increased viewing time suggests that the putative top-down surrounding representation becomes stronger with viewing, so that slightly more surrounding space is later misattributed to vision. Unexpectedly, disorientation slightly increased the BE error. As suggested by the inversion effect (Yin, 1969), disorientation may limit the quality of visual encoding, thus increasing similarity between visual memory and memory for the surrounding top-down scene structure, inducing more BE for brief, disoriented views.

53.531 **Boundary extension in children vs. adults: What developmental differences may tell us about scene representation**

Erica Kreindel[1](ekreindel@psych.udel.edu), Helene Intraub[1]; [1]University of Delaware

People remember seeing beyond the boundaries of a view (boundary extension; BE). One explanation (Multisource Model; Intraub, 2011) is that scene representation is not solely visual, but also includes multiple top-down sources of input (e.g., amodal perception, layout extrapolation). At test, people misattribute to vision what was originally acquired through top-down sources (i.e., a source monitoring error) resulting in BE. To assess this hypothesis we drew on the developmental observation that young children are more susceptible to source monitoring errors amongst similar sources than are adults (Lindsay, 2008). Would preschoolers therefore remember seeing more extra-stimulus area after viewing a photo-scene than would adults? In Experiment 1 preschoolers' (N= 15; Mean age = 4.6) and adults' (N= 24; Mean age = 18.7) drawings of a just-studied photograph yielded BE. Background area was increased, reducing the size of the main object by 16% (children) and 11% (adults); no difference. However, in Experiment 2 an immediate forced-choice task revealed a clear difference. On each of 40 trials, participants studied a close-up or wider-angle view (15 s) which was immediately replaced with both views (close-up and wider-angle; one identical to the stimulus). Closer-wider test pairs differed by 15% or 30% zoom. If BE occurs, we should observe error asymmetry: more errors on close-stimulus trials (selecting the wider view) than wider-stimulus trials (selecting the closer-view). Children's memory reflected BE for 15% and 30% test pairs; adults only for 15% pairs (minimal errors occurred at 30%). A significant interaction (stimulus view x pair similarity) in each group showed that children's strongest BE (close-stimulus errors > wider-stimulus errors) was at 30% zoom [F (1,14)=7.26, p<.017], whereas for adults it was at 15% zoom [F (1,23)= 13.00, p<.001]. Preschoolers made the same BE error as adults, but misattributed a greater swath of surrounding space to vision.

53.532 **Using Boundary Extension To Assess Memory For Scene Views Across Changes In Object Orientation**

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We asked whether the spatial expanse of scene views can be judged across changes in object orientation based on predicted differences in boundary extension (BE) as a function of object orientation. Stimuli were photographs of overhead scene views showing an object against a natural ground surface (e.g., a flashlight on grass), shown within a square view-window. Objects filled views in one dimension only (e.g., a screwdriver, hammer). On each trial, observers (N=48) viewed a 250-ms picture followed by a 250-ms mask and test picture. Half the objects were vertical; the other half horizontal. On half the trials, the object in the test view was in the same orientation as the stimulus view (VV and HH trials); in the other half, it was in the complementary orientation (VH and HV trials). Stimulus and test views were always close-ups. Horizontal-vertical viewing information was made comparable by placing square frames in front of monitors, with square cutouts for stimuli. At test, observers rated the test picture's view as the same view, more close-up, or more wide-angle than the stimulus view on a continuous sliding scale. A negative rating significantly less than zero ("same view") would indicate BE. We hypothesized that vertical-object stimuli would elicit more BE than horizontal-object stimuli (as in Dickinson et al., VSS 2011), resulting in VH stimulus-test pairs being rated more similar than HV pairs. In addition to finding significant BE for VV and HH trials (mean ratings: –.19 and –.13; both ps <.001), we found a VH-HV asymmetry: VH pairs were rated as more similar than HV pairs (–.05 vs. –.28; p <.001), which is analogous to the CW-WC asymmetry indicative of BE. The results suggest that observers can judge the spatial expanse of views independent of object orientation and provides further support for the finding that vertical-object scene views are perceived as more close-up than horizontal-object scene views.

53.533 **Quantifying boundary extension in scenes**

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After viewing a picture of a scene, people remember having seen a wider-angle view than was originally presented. This phenomenon, known as "boundary extension" (Intraub & Richardson, 1989), is very robust across viewing contexts, but few studies have attempted to quantify the magnitude of this effect. In this study, we investigate the magnitude of boundary extension produced by images at various levels of zoom, and examine the roles of foreground objects and background textures in this effect. We ran two boundary extension experiments using two different image sets. Training sets were created by cropping the images so that the central object would fill a particular proportion of the image height (ranging from 45% to 90%). Participants viewed a stream of training images with a particular level of zoom and were asked to remember the images in as much detail as possible. At the end of the sequence, participants were shown the same images again in an interactive window, and they were asked to zoom in or out on each test image to recreate the view which they had previously seen. We obtained a consistent boundary extension effect: across image sets and conditions, people generated wider-angle views in which the central object was about 5% smaller than it had been in the original image. We ran another experiment in which, rather than zooming the entire image to produce the remembered view, participants were asked to manipulate the central object or the background independently. When asked to resize the central object, participants mimicked boundary extension by making the central object about 6% smaller than in the original. However, they showed the opposite effect when manipulating the background: they chose a view in which the background texture was about 6% larger than it had been in the original.

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53.534 **Effects of Clutter on Boundary Extension: Volume or Detail effects?**

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Boundary Extension (BE), the tendency to remember a more wide-angle version of the scene than was actually viewed, has been linked to processes engaged in spatial layout perception. Prior research showed that cluttered natural scenes produce more BE than uncluttered ones. The cluttered scenes included more objects (more visual detail) that took up more space than the uncluttered scenes. However, it was impossible to tell which of these factors, the space that objects take up, the amount of detail present, or both, are important in enhancing BE. In the current study, these factors were teased apart by using computer modeled volumetric scenes. Two versions of 16 scenes were created. A cluster of objects occupied the same area in both versions. The amount of detail (number of objects and texture elements) making up this cluster varied. One version had comparatively little detail (e.g., two sofas and a chair in front of an almost empty entertainment center with lamps on each side). The other version had much more detail occupy the same area of the room (e.g., 7 chairs with several coffee table books, plants, coffee mugs, a telescope, lamps and a now crowded entertainment center). Participants viewed eight less detailed scenes and eight more detailed scenes, in random order, for 5 s each. Scene version was counterbalanced across participants. In the test, the same pictures were shown and participants had to indicate if the pictures were more close-up or more wide-angle than before. More BE was obtained for the less detailed versions. This finding indicates that the effect of clutter is driven by the amount of space the object cluster takes up in the view presented, not by the amount of detail. Large amounts of detail seem to detract from viewers' extrapolation of scene layout beyond the visible area.

53.535 **Seeking the boundary for boundary extension**

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Boundary extension (BE) is a phenomenon in which participants' memory about the extent of the borders in a previously viewed scene is biased towards including additional scene information. Current theories suggest this error of commission is a source monitoring error between actual scene material and participants' representation of the scene containing actual and expected scene material. According to this view, when participants make an error they are biased to chose the representation consisting of expected scene information; in other words, they extend the boundaries of the scene with expected scene material. In an earlier study (VSS, 2011), we sought to evaluate the necessity of expectation by removing cues thought to encourage amodal continuation and hence BE (e.g., familiarity, occlusion, semantic content, texture gradients) by using abstract shapes on random dot backgrounds. Despite removing semantic content, BE was predicted only when occlusion cues were evident at the borders of our images (e.g., when an expectation of continuation was present). The overall results showed BE in all conditions regardless of expectation; however, in a few conditions we could not eliminate the possibility of boundary restriction. The current study, using a new, larger set of abstract stimuli with enlarged background dots, showed BE in all conditions and no evidence of boundary restriction or normalization. Thus according to current theories, even though BE

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should not have occurred when expectation of extension was absent (e.g., no occlusion at borders, no background dots) we have now consistently shown it with these type stimuli. Perhaps, BE is even more ubiquitous than initially thought and may represent a fundamental aspect of visual perception. Additional experiments will be discussed in which we parametrically vary other stimulus variables including the percentage size change between close and wide angle versions of images with and without objects.

53.536 **The Relative Effectiveness of Different vs. Shared Mask Features on the Processing of Scene Gist**

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Backwards masking reduces stimulus visibility and allows researchers to investigate the dynamics of perceptual processes. However, the mechanisms underlying this attenuation remain unclear. How do the visual features of a mask interact with the perception of a target scene? Is it more difficult to categorize a scene when it is masked by an image sharing visual or conceptual features? Here, we tested six different mask types created from Image Types that were either (1)identical to the target image or (2)different images in which the mask was created from a different category scene. The Mask Types were: (1)different-scene, (2)textures from the Portilla-Simoncelli algorithm (2000),3)phase-scramble,(4)pixel-scramble, (5)10-pixel block-scramble and (6)100-pixel block-scramble. Participants were shown colour photographs of scenes for either 20 or 50ms, followed by one of six mask types for 50ms. Participants were then shown a scene category name and instructed to indicate whether it matched the target scene. A mask was deemed more effective when categorization accuracy was poorer. For the 20ms condition, Bonferroni-adjusted comparisons revealed an interaction between Image Type (identical versus different) and Mask Type such that for the different-scene and 100-pixel block scramble masks, different image masks were more effective (55%) than identical image masks (85%). Interestingly, the most effective mask for both image types was the 10-pixel scramble mask (Different:59%, Identical:58%). Of the remaining mask types, masking was moderately effective with overall higher accuracy rates(68%-78%) and differences between Image Types were small or non-existent (.04%-5%). The pattern of results suggests that masks are more effective when derived from a different scene category and when some conceptual information can be derived (Potter, Staub & O'Connor, 2004), indicating that mask efficacy is increased when masks differ in both perceptual and conceptual information from the target image.

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53.537 **It's not just gist! Recognition memory for scrambled scenes with limited attentional resources**

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The visual system can rapidly extract the 'gist' of complex visual scenes (Potter, 1975; Potter et al., 2010). Researchers argue that gist perception involves a global analysis of a scene's spatial properties, such as its spatial layout, without necessarily encoding individual object details (Oliva & Torralba, 2001). Alternatively, we might analyze diagnostic objects in a scene (Stigliani et al., 2010; Quattoni & Torralba, 2009). We sought to determine if participants could extract more than the gist of a scene, even when attentional demands were high and scene information content was low. In Experiment 1, participants performed a demanding digit counting RSVP task at fixation while simultaneously categorizing a target scene presented briefly behind the fixation task (Cohen & Alvarez, 2011). Participants first reported the number of digits they observed and then reported the category that best matched the target scene. Participants were then asked to select the specific target scene among 5 same-category distractors. Surprisingly, participants correctly selected 50% of the specific target scenes among same-category distractors even when scenes were presented for 67 ms and were masked before and after with random colored blocks (chance performance was 16.7%). In Experiment 2, we scrambled scenes into 4x4, 7x7 or 10x10 blocks then shuffled them to create target scenes that had disrupted spatial layouts and minimal object information. Even when target scenes were scrambled into 10x10 blocks and presented for 67 ms, participants correctly identified the gist for 66% of the target scenes while performing the digit task. Critically, participants were also able to select the correct unscrambled version of the target scene among 5 same-category distractors 40% of the time. Together, these results suggest that participants are able to encode details beyond the gist of a scene even with limited attentional resources or when the scenes lack spatial layout or object information.

53.538 **Scene Gist Meets Event Perception: The Time Course of Scene Gist and Event Recognition**

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Picture stories are composed of discrete events based on goal-directed behaviors. When perceiving an event, a working-memory representation of that event is created, called an event model, which makes predictions about what may occur next in the story. Studies have shown that changes in the setting (the scene gist) and character action often indicate that a new event model is needed, but it is unknown which of these two features is processed first when constructing an event model. We examined the time-course of scene gist and action categorization to determine which is categorized earliest in scene perception. Images were categorized according to their superordinate scene gist (Indoor vs. Outdoor), basic level scene gist (e.g., Park vs. Yard), or action (e.g., Raking vs. Mowing). Rosch et al.'s (1976) basic level theory predicts that basic level scene categories should be recognized prior to those at the superordinate level. However, recent studies (e.g., Loschky & Larson, 2010) have shown the opposite to occur early in scene perception. Alternatively, eye-movement studies show an attentional bias to fixate people in scenes, which predicts that actions may be categorized prior to scene categorization. We tested these three competing hypotheses by randomly assigning participants to one of three categorization tasks (superordinate scene, basic scene, or action). Scenes were presented for 24 ms, with masking SOAs of 23, 60, 106, 200, and 376 ms, and participants then responded "Yes" or "No" to a valid or invalid category label. The results showed that image categorization occurred in a global-to-local fashion. Namely, at early SOAs (e.g., 23 ms), superordinate scene gist categorization showed the greatest sensitivity, followed by the basic level, and then actions. Thus scene gist is categorized prior to actions, suggesting that scene gist is the first stage in perceiving events, constructing event models, and comprehending picture stories.

53.539 **Viewpoint dependent and independent contextual cuing effect**

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[Purpose] When we move, the movement changes the viewpoint. Despite such viewpoint changes, we perceive the objects and object layouts unchanged in the space. This indicates that our visual system has viewpoint independent representations of objects/layouts. We examined whether the spatial representations can be obtained implicitly and whether there is a viewpoint dependent representations that is independent on self-motion. [Experiment] We adopted contextual cuing effect (CCE) to investigate implicit learning of spatial layouts. The CCE is a learning effect of spatial layout in visual search displays and is known to be an implicit learning effect. Without noticing the repetitions, visual search performance increases by repeating a visual search task. We examined whether the CCE is obtained with viewpoint changes due to self-motion. Visual search displays were presented on a head mount display so that the viewpoint of the display and the head position were controlled independently. We compared the CCE between with and without self-motion in a visual search task where the stimulus viewpoint was changed and also where it was not. [Results] We found the CCE with self-motion when the display changed according to the self-motion with the viewpoint change of 40° while no CCE with that of 90°. When the display changed without self-motion, however, the CCE disappeared with 40° change. This indicates that there is an implicit learning effect in the spatial coordinates but with a limited range of viewpoint changes. The CCE was also found when retinal image was kept with viewpoint changes. This indicates that viewpoint specific presentations of retinal information, which is obtained implicitly, are maintained independently of viewpoint independent spatial representations. [Discussion] Our results suggest that object layouts are learned implicitly in two different processes: one works in the spatial coordinates and the other in the retinal coordinates.

53.540 **The influence of stimulus duration on visual illusions and simple reaction time**

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Participants usually respond faster to larger objects as compared to smaller objects. In order to perceive an object's size, the brain needs to integrate contextual information such as object distance, an effect elucidated by various visual illusions. Accordingly, the perceived size of identical objects can differentially be altered via depth cues that create differentially perceived object distances. Recently, it has been demonstrated that simple reaction times are modulated by the perceived rather than by the retinal size of an object. This indicates that responses are generated subsequent to distance and retinal size integration. However, the timing aspects of these integration processes are largely unclear. Therefore, the present study investigated the influence of stimulus duration on size - distance integration by means of a simple reaction time paradigm. In two experiments we verified the effect that reaction times are susceptible to a variant of the well known Ponzo illusion. In the first experiment, participants reacted faster to perceptually longer lines in front of an illusion inducing background, whereas no such effect was associated with a neutral background. Subsequently, the second experiment revealed that this effect depends on stimulus duration time. Durations shorter than 40 ms did not elicit the reaction time effect. Hence, the present findings indicate that the visual system requires a minimum visual input in order to integrate context and object information. Before this minimum input is available the system seems to rely on lower visual representations.

53.542 **Evidence for perceptual convergence of object- and layout-based scene representations**

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Behavioral data suggest that human scene recognition draws heavily upon analysis of global scene properties, such as three-dimensional layout (Greene and Oliva, 2009). At the same time, the identities of objects within scenes tend to correlate strongly with scene identity, making them potentially useful information sources during scene recognition. Consistent with this, recent work has shown that scene recognition is hampered when objects are removed, and that object-evoked response patterns in object-selective occipitotemporal cortical areas can predict patterns evoked by scenes associated with those objects (MacEvoy and Epstein, 2011). These results suggest the existence of an alternate, object-based route to scene recognition. In the present study, we asked whether these layout- and object-based routes converge at the perceptual level by examining the impact of objects upon perceived spatial layout of scenes. We used a web-based survey to obtain subjective spaciousness ratings of 500 exemplars of bathrooms, a scene category characterized by highly diagnostic objects and a wide range of spaciousness among exemplars. Similar to the design of Greene and Oliva (2010), subjects in the main experiment were adapted to scene exemplars drawn from either top or bottom quintile of spaciousness ratings and then asked to provide ratings of the spaciousness of exemplars drawn from the middle three quintiles. Adapting scenes were shown either with diagnostic objects masked or visible. Spaciousness ratings of middle-range exemplars were significantly elevated or lowered after adaptation to bottom- or top-quintile exemplars, respectively, relative to unadapted control ratings. However, the magnitudes of adaptation effects in both directions were significantly smaller when subjects were adapted to scenes with visible diagnostic objects. The presence of diagnostic objects appears to have tempered excursions in the perceived spaciousness of adapting scenes, indicating that layout- and object-based scene processing channels converge at a perceptual level.

53.543 **Effects of object facing direction and implied motion on preferences for spatial composition**

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Palmer, Gardner, and Wickens (2008) found an "inward bias" in aesthetic preferences for the position of a single object inside a frame that depended on its facing direction: right-facing objects were preferred left of center and left-facing objects were preferred right of center. They hypothesized that participants would also prefer objects that characteristically move forward (e.g., people, dogs, and cars) to be located farther from the center of the frame than objects that are characteristically static (e.g., flowers, chairs, and teapots) to provide more space for their forward motion, but no difference was detected between these two object classes. In the present experiments, we tested whether the motion direction and speed of self-propelled moving objects influenced the preferred horizontal position of forward facing objects. We used images of left- and right-facing humans, horses, and cars that depicted different motion directions and speeds. The results showed that motion direction trumped facing direction for forward/backward divers, in that divers facing one direction and moving in the opposite direction (i.e., backward divers) were preferred to be facing out of the frame but moving into it. Additional conditions investigated the effects of implied speed using images of standing, walking, jogging, and running humans and standing, walking, trotting, and galloping horses. Inward biases were again present, but no differences in their magnitude were detected in the different speed conditions. These results suggest that both facing direction and motion direction affect preferred horizontal positioning, but not motion speed.

Acknowledgement: NSF

53.544 **Understanding the intrinsic memorability of images**

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Artists, advertisers, and photographers are routinely presented with the task of creating an image that a viewer will remember. While it may seem like image memorability is purely subjective, recent work shows that it is not an inexplicable phenomenon: variation in the memorability of images is consistent across observers. Some images are intrinsically more memorable than others, independent of observers' contexts and biases. In this work, we are interested in understanding what characteristics of images make them more memorable than others. We used the publicly available memorability dataset of Isola et al., and augmented the object and scene annotations with interpretable spatial, content, and aesthetic image properties. We used a feature selection scheme with desirable explaining-away properties to determine a core set of attributes that concisely characterizes the memorability of an image. In particular, we compared two greedy feature selection methods: 1) selecting the set of features that maximizes an approximation of the mutual information between the feature set and memorability, and 2) selecting the set of features that maximizes the performance of a memorability predictor. Our selected features are compact, yet effective at predicting memorability. They perform significantly better than randomly selected sets of features with comparable complexity. Since our features were interpretable attributes, our selections allow for a simple and understandable explanation of memorability. We find that images of active, enclosed spaces containing people are memorable, while images of peaceful scenes with no "story" are not. Contrary to popular belief, "unusual" and aesthetically pleasing scenes do not tend to be highly memorable. We also predicted these characteristics of images automatically from low-level image-features, resulting in a fully automatic approach to predicting memorability. This work represents one of the first attempts at understanding intrinsic image memorability, and lies at an emerging interface between human cognition and computer vision.

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53.545 **Is color information important for fearful scene perception?**

Anne Boguslavsky[1](Anne.M.Boguslavsky.13@dartmouth.edu), Bingbing Guo[1,2], Ming Meng[1]; [1]Dept. of Psychological and Brain Sciences, Dartmouth Col., [2]Dept. of Biomed. Engin., Chongqing Univ.

Humans heavily rely on vision to evaluate safe versus dangerous environments. It is debated whether color information contributes to the perception of affective scenes (Cano et al., 2009; Codispoti et al., 2011). Previous studies compared scenes with strong emotional valence and, as a control condition, neutral scenes. However, we argue that if color plays a significant role in affective scene perception, the effect should be most pronounced in stimuli with weak or moderate emotional valence, since obviously fearful scenes may be perceived as such with and without color. A set of 157 colorful images devoid of human faces but with a wide range of other contents (e.g., fires, spiders, car crashes) was collected from the Internet. We tested the effect of color and its interaction with novelty of the images by asking participants to rate the fearfulness of each stimulus. Participants were divided into two groups. One group saw the images in color and then in gray-scale while the other group saw the images in gray-scale first. A mixed-model ANOVA revealed significant main effects of both color and observing order. The interaction between the effects of color and observing order is also significant with the difference between color and gray-scale images being greater when participants saw the images the first time rather than the second time, suggesting perhaps a color priming effect. Moreover, the effect of color was found to be the strongest for images that were rated as low or moderately fearful, and not significant for images that were rated as highly fearful, despite the fact that the ratings did not reach the maximum suggesting that the results were not caused by a ceiling effect. These results are consistent with our prediction, highlighting the importance of using stimuli across a full spectrum of valence to study affective scene perception.

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53.547 **Aesthetic preference of oriented content in broadband images**

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Visual encoding biases may affect the aesthetic perception of an image (Zeki, 1999). Here we consider how biases in processing orientation (anisotropic suppression; Haun and Essock, JOV 2010) may impact aesthetic preferences. Visual performance is anisotropic showing an oblique effect for line (narrowband) stimuli and a horizontal effect for broadband stimuli (Appelle, 1972; Essock, et al., Vision Res., 2003). Aesthetic preference for classic Mondrian paintings rotated to different orientations favors content oriented horizontally and vertically (Latto, et al., Perception 2000; Haun, et al., 2006). Haun, et al. replicated this result and also found the same preference for Mondrian "noise" stimuli made with random phase. Furthermore, broadband noise images that were more heavily dominated by a single orientation band were more preferred regardless of which orientation was dominant and this preference increased as strength of the dominance increased. However, the established difference in salience to different orientations of content (horizontal effect) may have influenced these results. The current study examined the aesthetic preference for (1) broadband stimuli containing perceptually matched content of different orientations and (2) for images of natural scenes containing differing ratios of orientation biases. These two procedures addressed whether people prefer orientations which are predominant in natural scenes and suggested that aesthetic preference is related to the anisotropic processing of orientation. In Experiment 1 suprathreshold matches were first obtained, the subjects' preference for broadband noise images consisting of orthogonally oriented components was evaluated. In Experiment 2 subjects' preference for natural scenes with varied amounts of horizontal/vertical and cardinal/oblique bias were measured and related to the power difference. Results suggest a relation of orientation bias and aesthetic preference.

Perception and action: Reaching and grasping

Tuesday, May 15, 8:15 - 12:15 pm

Poster Session, Vista Ballroom

53.548 **When reaching is risky, disgust influences estimates of exocentric distance.**

Kyle Gagnon[1](kyle.t.gagnon@gmail.com), Michael McCardell[1], Samantha Fuhrman[1], Jeanine Stefanucci[1]; [1]University of Utah

Research suggests that estimates of perceived space may change while in an emotional state. Here we test whether perceived exocentric distance changes when in a state of disgust. Given that the function of disgust is to help us avoid pathogens, we hypothesized that estimates of distances between a benign object and a pathogen source would be more accurate than estimates of the same distances in a control condition. Such a finding would subserve the function of disgust and ultimately enhance action planning. Participants in the disgust condition viewed experimentally constructed feces (that reliably induced disgust) in the center of a table while participants in the control condition viewed an eraser that did not induce disgust. A cookie was placed at one of twenty locations around the feces or eraser on each trial. All participants were asked to imagine picking up the cookie. Then they instructed the experimenter to adjust a tape measure until its length perfectly matched the distance between the cookie and the feces or eraser. Finally, participants were asked to pick up the cookie and place it on a plate next to them. The results show that participants in the feces condition estimated the distance from the cookie to the feces to be significantly shorter and were also more accurate. However, this effect was only found for cookie locations that would require a reach trajectory that went over or near the feces. Overall, the data suggest that estimates of perceived distance become more accurate while disgusted to help us avoid contact with pathogens when planning for future actions. Although the task was not purely perceptual, it appears to be influenced by imagined action or the intent to act.

53.549 **Behavioural and electrophysiological evidence of visual vector inversion in antipointing**

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Antipointing requires suppressing a stimulus-driven response and reaching mirror-symmetrical (180° spatial transformation) to an exogenously or endogenously presented target. Notably, antipointing produces longer response latencies than their stimulus-driven counterparts (i.e., propointing) and elicits a visual-field specific pattern of endpoint bias (Maraj and Heath 2010: Exp Brain Res). In particular, antipointing trials in left and right space respectively under- and overshot veridical target location: a pattern of results consistent with a perceptual representation of visual space. The present study examined the contemporaneous behavioural and event-related brain potentials (ERP) of pro- and antipointing to determine whether the visual-field specific endpoint bias in the later task is related to: (1) the reallocation of visual attention and/or (2) the visual remapping of target properties in mirror- symmetrical space (i.e., vector inversion). A priori, we identified the N100 and P300 as providing the candidate ERP components associated with attention reallocation and vector inversion, respectively. In terms of target presentation, participants were provided advanced information pertaining to the nature of the task (i.e., pro- vs. antipointing) and electroencephalographic data were collected following target onset. As expected, antiponiting - but not propointing - produced a visual-field specific pattern of endpoint bias. Moreover, the N100 at electrodes PO7 and PO8 showed a lateralized response to target presentation that did not differ between the pro and antipointing conditions. In contrast, the later occurring P300 showed a reliable (and bilateral) between-task difference. Thus, our ERP data indicate that antipointing is mediated by a process of visual vector inversion. What is more, the combined ERP and behavioural data indicate that vector inversion is subserved via perception-based visual networks.

Acknowledgement: Supported by the Natural Sciences and Engineering Research Council of Canada

53.550 **Updating of motor specifications in open-loop conditions during movement time**

Jeppe H. Christensen[1](jabbahc@gmail.com), Jens H. Christiansen[1], Søren Kyllingsbæk[1]; [1]Center for Visual Cognition, Department of Psychology, University of Copenhagen

The planning-control model proposed by Glover (2004), suggests that an unfolding visual representation gradually assumes control of goal-directed action. Can the gradual build up of control during movement time be quantified by looking at performance as a function of time from movement onset to which no further grasp corrections are made? Participants (N=7) were asked to grasp a bar of light presented briefly (40ms) on a computer display

Tuesday AM

and specify it with two separate features, namely angle (30°-70°) and length (6cm-9cm). Hand and finger movements where acquired using a motion capture system that ensured sampling of the full grasp cycle. Statistical analysis of the continuous angle and aperture between index finger and thumb were conducted from movement onset to terminal position. A novel measure of accumulated variance was employed to each trial, quantifying them in five discrete stages going from very late to very early time of specification. Results show that successful performance for both features are highly dependent on the time to which no further grasp corrections are made (chi2 test of independence; angle: $p<0.001$ length: $p<0.001$), sooner the better. A simple speed-accuracy trade-off would have predicted the inverse relationship. Trial-by-trial accuracy can be predicted from the specification time. Motor specification of features in an open-loop condition updates during movement time in a feed-forward manner (no visual feedback). Thus, the results support the conjectures of the planning-control model.

53.551 **Intended and spontaneous motor behavior under a 3D perspective visual illusion**

Jillian Nguyen[1,2,5](jinguyen@eden.rutgers.edu), Robert Isenhower[3,5], Joshua Dobias[2], Polina Yanovich[2,5,6], Jay Ravaliya[2,4], Elizabeth Torres[3,5,6], Thomas Papathomas[2,4]; [1]Department of Neuroscience & Cell Biology, Rutgers University & UMDNJ, NJ USA, [2]Laboratory of Vision Research, Center for Cognitive Sciences, Rutgers University, NJ USA, [3]Department of Psychology, Rutgers University, NJ USA, [4]Department of Biomedical Engineering, Rutgers University, NJ USA, [5]Sensory-Motor Integration Lab, Rutgers University, NJ USA, [6]Department of Computer Science, Rutgers University, NJ USA

OBJECTIVE: To test the hypothesis that top-down visual processes affect our visual percepts and leak into our sensory-motor system. In particular, we ask whether reaches toward a target embedded in a 3D scene are governed by the real or the perceived geometry. METHODS: 3D stimuli: a proper- and a reverse-perspective. (1) In the proper ("forced") perspective, the perspective-painted cues were congruent with the bottom-up signals of binocular disparity and motion parallax. (2) In the reverse-perspective, the painted cues competed with the bottom-up signals, thus eliciting bistable percepts: (a) The veridical depth percept. (b) The illusory reverse-depth percept in which concave parts are perceived as convex and vice versa; as a result of the illusory percept, the perceived 3D orientation of surfaces is affected drastically. Subjects viewed the stimuli and either pointed to or grabbed at planar disk targets at instructed fast or slow speeds while we recorded their movements. RESULTS: Hand trajectories intended toward targets remained invariant to changes in speed according to various geometric measures. However, the hand-paths were significantly affected by the illusion, particularly with respect to their lengths and curvature. These effects were even stronger when comparing the endpoint accuracy of the reverspective-veridical and reverspective-illusory percepts. Additionally, strong differences were found between the reaches intended toward the target and the spontaneous transitions retracting the hand to its resting position. These significant differences in the moving hand transferred to the resting hand, thus suggesting a type of motor-overflow with the increase in cognitive load that cannot be explained by the instructed changes in speed alone. CONCLUSIONS: Overall we find compelling evidence that top-down visual processes affect both our visual percepts and our sensory-motor systems. These effects are separable according to sensory-motor patterns of variability that change the noise levels between intended and spontaneous actions.

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53.552 **Distractor Interference in one- and two-handed selective reaching tasks.**

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In one foundational study of action-centred attention (Tipper et al. 1992), two patterns of distractor interference were reported: the ipsilateral effect - distractors on the same side of space as the effector caused more interference than distractors in the opposite side of space; and, the proximity effect - distractors closer to effector cause more interference than farther distractors. These patterns of interference are thought to emerge because distractors ipsilateral and closer to the effector activate salient competing responses and require more time to inhibit. One aspect that has not been addressed is how interference emerges when individuals need to choose responses between the hands. We hypothesized that distractors which activate responses for the other limb may cause greater interference than distractors that alter the movement specifications within a limb. This prediction is based on research showing that the specification of the arm occurs before the specification of movement direction and amplitude (Rosenbaum, 1980). Participants in the present study executed reaching movements to 1 of 4 (2 left, 2 right) possible target locations with and without a distractor. In Experiment 1, participants made ipsilateral reaches (left hand to left targets, right hand to right targets). In contrast to studies using one-handed reaches, a "contralateral effect" was observed in which distractors affording responses for the other hand caused more interference than distractors affording responses for the same hand. In Experiment 2 (a control study similar to Tipper et al., 1992), participants used their right hand to reach to all targets. Contrary to Experiment 1, a contralateral distractor interference effect was not observed. Together, the findings from the present research support the notion that attention is influenced by the actions being performed and, further, support Rosenbaum's idea that the specification of the effector occurs earliest in motor planning.

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53.553 **Another attempt to measure tool-based compression of visual space (N=50)**

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Does intending to use a tool that extends reach compress visual space (Witt, 2011)? Last year we reported a failed attempt to exactly replicate such an effect, (Ontiveros, et al., 2011; see also de Grave et al., 2010). Here we adopted an instructional manipulation developed by Woods et al. (2009), to see if tool-based space-compression effects might be easier to reproduce with specific instruction sets. To avoid experimenter effects, we kept the experimenter blind to instruction condition by using a computer to assign participants to condition and to provide detailed instructions. Each participant was alerted (by the computer) to three different ways to view a shape matching task for a triangular shape on a table surface: (1) match the actual shape (what you believe the shape to be), (2) match the apparent shape (the way it looks) or (3) match the way the shape "feels" to you taking into account everything about the situation. Each participant was then specifically instructed to make matches (on a computer screen) according to one of these three criteria. Half of the subjects used a tool to reach the far point of the table shape after each trial. The other half reached with their hand. We had hypothesized that people in the hand conditions might be the source of variation because people normally overestimate the farthest reach of their hand and thus would receive feedback on some trials indicating that targets were farther than they appeared. Our data showed a trend in this direction: Participants in the "feel" version of the hand condition tended to provide higher estimates of the height-to-base aspect ratio of the shapes on the table than in the other five cells of the design.

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53.554 **In the palm of my hand: hand functionality biases shifting of exogenous visual spatial attention**

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Detection of visual targets is enhanced in the grasping (functional) space of the hand relative to the non-grasping space (Lloyd et al, 2010; Reed et al 2010). We asked whether this advantage is specific to detection or whether more complex mechanisms such as discrimination also benefit. Using a Posner cueing paradigm we conducted two experiments to examine how functional hand space modulates exogenous visual spatial attention. In a between-groups design, participants positioned either their left or right hand at the corresponding lower corner of a monitor and with the palm in the prone (palm down) or supine (palm up) orientation. Targets (a yellow circle or a yellow triangle) were cued validly or invalidly (Cue duration 250ms; SOA 250ms; Target duration 250ms). They appeared on the monitor to the right or left of a fixation cross in the same or opposite hemispace as the hand. In experiment 1, using their other hand, participants responded to targets with a mouse click. Response times were faster to validly than invalidly cued targets, and there was a stronger cuing effect for targets occurring within perihand space compared with those in the opposite hemispace. Palm orientation did not modulate performance. In experiment 2, stimuli

Tuesday AM

 See page 3 for Abstract Numbering System

and hand position and orientation were the same, but this time participants discriminated between the circle and the triangle with a right or left mouse click. Supine palm orientation was associated with faster responses to targets appearing in the same hemispace as the hand. These findings indicate that the functional space of hands enables a relatively complex attention mechanism, discrimination rather than detection of targets. Lloyd, D. M., et al (2010). Brain and Cognition, 73(2), 102-109. Reed, C. L., Betz et al (2010). Attention, Perception, & Psychophysics, 72(1), 236-245.

53.555 **Effects of environment constraints and judgments about action on distance judgments**

David Lessard[1](david.lessard@psych.utah.edu), Sarah Creem-Regehr[1], Jeanine Stefanucci[1]; [1]Department of Psychology, University of Utah

To determine action capabilities, an actor must compare environmental features to the actor's individual body and capabilities (Gibson, 1979). Previous research, such as Witt et al. (2005), has shown that changing an actor's ability to reach by changing the body influences judgments of distance to reachable objects. However, it is unclear whether environmental features that could affect reaching will also alter estimates of distance. The current studies tested whether environmental features that constrain reaching would influence estimated distance to reachable objects. In Experiment 1, participants judged distances to a small object when it was behind a clear, reach-limiting Plexiglas barrier and also when the barrier was absent. Participants estimated their ability to reach the object (yes or no response), and then visually matched the perceived distance to the object. For analysis, we created ratios that divided distance judgments by the actual distance to the object. The results indicated a main effect for the presence of the barrier, such that participants judged the distance to the object as farther when the object was behind the barrier than when the barrier was absent. The barrier did not significantly affect reachability judgments. Experiment 2 investigated whether intent to reach is necessary to induce the effect of the barrier. Participants performed the distance-matching task but did not give estimates of their ability to reach the object; reaching was not mentioned. Experiment 2 did not result in a significant difference for distance judgments when the barrier was present versus absent. These results suggest that environmental features that constrain action can influence distance estimations but only when the actor is thinking about performing a distance-relevant action. Further experimentation is in progress to test whether accounts of motor simulation or task expectations may explain these effects.

53.556 **Sequence effects in grasping: evidence for an implicit location-unspecific action memory**

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The preceding pick-and-place task influences the kinematics of a subsequently executed task. Both spatial properties as well as non-spatial properties of recent actions have been demonstrated to affect movement planning and execution on a given trial. An influence of non-spatial properties of recent experience has hitherto not been examined in an intertrial paradigm - that is, in the previous intertrial studies, only one of the two factors object location or object presence was variable across trials, at a time. We investigated whether intertrial priming effects of object features are location specific or can be generalized over changes of location. Participants grasped either a wine or a water glass from two different starting positions and placed it onto a box. The glass (wine or water) and the position of the glass (left or right from the resting position) were either the same or varied between trials. The results showed that repeating the same glass consecutively over two trials yields in faster movement planning and faster grasping movements independent of the position of the glass in the last trial. In contrast, repeating the starting position over two consecutive trials did not result in faster movement planning and grasping movements. Consequently, our results indicate that memory traces responsible for feature-based intertrial effects are not location specific, but can affect subsequent movements even when they differ in spatial parameters.

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53.557 **Practice Reduces the Effect of a Ponzo Illusion on Precision Grasping but not Manual Estimation**

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Most studies of pictorial illusions rely on session-wise averages – an approach that assumes that effects of interest remain constant across successive iterations of the response within a test session. Recent evidence, however, suggests that this assumption is not always justified. For example, our group has shown that the illusory influence of the Ponzo display on the apparent size of objects is mitigated with practice for 'awkward' grasps executed with the ring finger and the thumb of the right (dominant) hand over the course of three consecutive days of testing, but not for awkward grasps executed with the left (non-dominant) hand (Gonzalez et al., 2008). Notably, substantial within-session reductions in the illusory effects were observed for grasps executed with the right hand. Could mechanisms underlying the within-session reduction in illusory effect extend to 'precision' grasps executed with the thumb and forefinger? To answer this question, we asked participants to manually estimate the length of single targets with their thumb and finger aperture a matching amount or to grasp them in a blocked ABA design. In both tasks, participants' responses were correlated, with equal sensitivity, to target length, but only manual estimates remained consistently biased by the illusion. In contrast, the illusory effect on grasps decreased linearly over the course of testing. The consistency of the effect of the illusion across manual estimates cannot easily be attributed to a lack of haptic feedback, since the manual estimates of an additional group of participants were consistently affected despite picking up the same target immediately following each estimate. We offer three possible explanations that can account for our findings: low-level motor calibration, motor learning, and another that invokes cognitive or attentional set-shifting – a process through which the saliency of stimulus and task features is updated following a switch in task demands.

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53.558 **Visuomotor priming effects in grasping depend on the quality of cue processing**

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While repetition and semantic priming effects have been demonstrated robustly in numerous studies, there has been a debate about visuomotor priming effects, that is, whether seeing an object prior to movement initiation facilitates an action congruent with the visual properties of that object. While some studies provide evidence for a general visuomotor priming effect, others failed to find visuomotor priming effects and the factors causally influencing visuomotor priming are still unclear. In the present study, we investigated two potentially important factors, cue exposure time and quality of cue processing. We were interested in whether simple exposure time already had an impact on visuomotor priming effects or whether the quality of cue processing was relevant. We implemented four experimental manipulations in a pick-and-place task with natural objects (wine or water glass), using identical objects as cue and target objects. Two experimental conditions for cue exposure time (simultaneous vs. delayed cue-target presentation) were combined with two kinds of cue processing quality (cue memory task vs. no memory task). Speed and trajectories of the grasping movements were recorded via an electromagnetic motion tracking system. Grasping of the target glass was faster when the cue was congruent compared to when it was incongruent but only if participants had to remember the cue identity for the memory task. Time course of cue-target presentation alone did not affect grasping speed. Movement trajectories and velocity profiles were not affected. In summary, we provide evidence for visuomotor priming in a pick-and-place task simulating natural grasping situations but only if participants processed and memorized the identity of the cue. The results of the current study suggest that visuomotor priming effects depend on the quality of cue processing and cannot be explained by the simple exposure time to the cue.

Acknowledgement: Neuro-Cognitive Psychology, Ludwig Maximilian University Munich

53.559 **Goal-directed grasping: Visual and haptic percepts of object size influence early but not late aperture shaping**

Kendal Marriott[1](kmarrio4@uwo.ca), Scott Holmes [1], Jonathon Tay[1], Matthew Heath[1]; [1]University of Western Ontario

Previous work by our group has shown that visually derived grasping yields a dynamic adherence to the psychophysical principles of Weber's law (Heath et al. 2011: Neurosci Lett; Holmes et al. 2011: Vis Res). In particular, aperture variability (i.e., just-noticeable-difference scores: JND) during the early - but not late - stages of aperture shaping increases with the size of a to-be-grasped target object. This 'dynamic' adherence was interpreted to evince that the early kinematic parameterization of a response is mediated via relative visual information and that later control is subserved via absolute visual information. The goal of the present study was to determine whether early JND/object size scaling similarly characterizes aperture trajectories when object size is defined haptically. Participants were provided a haptic preview of object size (i.e., 20, 30, 40 50 and 60 mm) by holding an appropriately sized target object with their non-grasping (i.e., left) limb. Following the preview, participants were cued to either manually estimate (i.e., perceptual task) or grasp (i.e., motor task) the target object, which was located 450 mm distal to a common start location. Importantly, responses in the motor task were performed with (no-delay) and without (i.e., delay) online haptic feedback, and for all tasks vision was occluded. As expected, manual estimations elicited a robust JND/object size scaling (i.e., Weber's law). For the motor task, both conditions showed an early scaling of JNDs to object size on par to the perceptual task; however, aperture shaping later in the response (> 50% of grasping time) did not. These results indicate that the time-dependent scaling of grip aperture to Weber's law represents a polysensory representation of object size. That is, vision and haptics provide relative and absolute information to support goal-directed actions.

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53.560 **Distinct visual metrics support the late stages of aperture shaping for 2D and 3D target objects**

Scott Holmes[1](sholme@uwo.ca), Kendal Marriott[1], Alisha Mackenzie[1], Maggie Sin[1], Matthew Heath[1]; [1]The University of Western Ontario, Department of Kinesiology

An issue of continued debate in the visuomotor control literature is whether a 2D target serves as a representative proxy for a 3D target in understanding the nature of the visual information supporting grasping control. For example, some studies have shown that absolute (i.e., Euclidean) visual metrics support both 2D and 3D grasping whereas other have not (c.f. Westwood et al. 2002 vs. Castiello 1998). In an effort to reconcile this issue, we applied the psychophysical principles of Weber's law and the computation of just-noticeable-difference (JND) scores to examine the aperture shaping profiles for 2D and 3D target grasping. In particular Weber's law states that changes in a stimulus that will be 'just noticeable' are a constant ratio of the original stimulus, thus, adherence and violation of JNDs to object size reflect the use of relative and absolute visual metrics, respectively. Participants grasped differently sized 2D and 3D objects (20, 30, 40, and 50 mm of width) and we computed the within-participant standard deviations of grip aperture (i.e., the JNDs) at decile increments of normalized grasping time. In terms of the early stages of aperture shaping, both 2D and 3D targets produced a linear scaling of JNDs to object size (i.e., Weber's law). Later in the response, 2D target objects showed a continued JND/object size scaling whereas 3D objects did not. Thus, results suggest that grasping a 2D target is mediated by a unitary and relative visual percept of object size whereas the early and late stages of aperture shaping for a 3D target are respectively subserved via relative and absolute visual information. We believe that such findings add importantly to the visuomotor control literature insomuch as they demonstrate that distinct visual metrics support the later stages of grasping 2D and 3D targets.

Acknowledgement: NSERC

Visual memory: Models and mechanisms

Tuesday, May 15, 2:30 - 4:30 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Daryl Fougnie

54.11, *2:30 pm*

Image memorability differences are stable over time delay

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The human visual memory system can store a remarkable amount of information in long-term memory. However, it appears to be the peculiar fate of memories that they must fade. Much work has examined the structure of forgetting for general classes of stimuli, but an item analysis of individual visual stimuli is lacking. Do all images fade alike? Recent work has shown that there are large differences between the memorabilities of different images, and these differences are quite consistent across context and observer, suggesting that the differences are intrinsic to the images themselves. Here we ask: could these differences arise from different rates of forgetting, or are the differences stable over time? We ran a Visual Memory Game on Amazon's Mechanical Turk in which participants viewed a sequence of images and indicated whenever they noticed a repeat. Each image repeated at most once for each participant, appearing at one of three possible delays: ~15 images back, ~100 backs, and ~1000 backs. We measured the memorability of each image at each delay as the proportion of times a repeat of the image at that delay was correctly detected. Strikingly, even after the shortest delay (10-20 images back; i.e. 24-48 seconds back), there were large memorability differences between the images, and these differences were remarkably similar to those at both longer delays (that is, image memorabilities at one delay correlated strongly with those at the other delays: r = 0.63, 0.68, and 0.55 for the three pairwise comparisons). Thus, it appears that the memorability differences we measured did not emerge slowly over time, but were already stable shortly after encoding. This suggests that differences in intrinsic image memorability reflect differences in how images are encoded and retrieved; in storage, all images may intrinsically fade alike.

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54.12, *2:45 pm*

Accessing visual memory distorts object representations

Judith E. Fan[1](jefan@princeton.edu), Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Princeton University

How does retrieving an object from visual memory affect its representation? Such operations could be inert, like reading a file from a hard drive. To the contrary, we propose that memory retrieval causally intervenes in shaping object representations. We presented observers with abstract symbols appearing in a random color, orientation, and angular location. Upon symbol offset, observers were cued to report one of these features from visual short-term memory (VSTM) by manipulating a black, canonically-oriented, centered version of the symbol (memory probe) until it matched the original symbol on the cued dimension. In a later test phase, only the memory probe was presented, requiring observers to report a cued feature from visual long-term memory (VLTM). In Experiment 1, we tested whether repeatedly probing the same feature of an object in VSTM would competitively bias VLTM representations, enhancing practiced information while suppressing unpracticed details. We found reduced error in reporting practiced features in the test phase relative to a passive viewing condition in which objects were equally familiar but probed only in the test phase, and increased error in reporting unpracticed features of objects for which another feature had been repeatedly practiced relative to passive viewing. In Experiment 2, we tested whether probing multiple features in VSTM would induce more inclusive VLTM representations, in which even information outside the scope of practice is enhanced. We found that practicing two different features yielded a more precise VLTM representation of an unpracticed third feature relative to accessing an unpracticed feature of objects for which one feature had been practiced twice. Taken together, these data suggest that accessing VSTM can induce two qualitatively different forms of learning, biasing object representations to repeatedly accessed features, and broadening them in the face of uncertainty about which features will be relevant in the future.

54.13, *3:00 pm*

Two objects remembered as precisely as one: Evidence that correspondence errors limit visual working memory

Gi Yeul Bae[1](freebird71@gmail.com), Jonathan Flombaum[1]; [1]Johns Hopkins University

What predominantly causes errors in visual working memory tasks? Items may sometimes fail to be represented, poor (and declining) representational precision may result in wrong judgements, and correspondence errors —comparisons between the wrong representation and an observed object— may lead to mistakes. If correspondence errors are a dominant cause, then increasing item discriminability (along task irrelevant dimensions) should improve performance. But typical laboratory tasks employ identical objects in all but the feature dimension tested, e.g. triangles of different orientations to test orientation. In Experiment 1, participants remembered the sizes of objects —triangles and circles— and each trial included one or two objects. Crucially, some two object trials comprised one of each shape, while others comprised identical shapes. At test, participants were probed with a single object changed in size by a variable amount, and they reported whether the change involved an increase or a decrease. Performance declined significantly for two object compared to one object trials when the two objects were from the same shape category. When they were different, however, there was no cost to performance. By fitting cumulative Gaussian functions to participant responses we could estimate representational precision, and we found no change in the precision of a size representation for a single item versus each of two differently shaped items. A second experiment found similar results in orientation memory for triangles and lamp-like objects (though with some costs associated with different item trials). Further experiments explored working memory for color. These results conflict with a central prediction of flexible-resource theories, that the biggest relative declines in representational precision should occur at a shift from remembering one item to two. We suggest that these results should catalyze further investigations into the possibility that item correspondence errors are the predominant cause of error in working memory tasks.

54.14, *3:15 pm*

Working memory resolution increases faster than capacity in visuomotor sequence learning

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As people become more familiar with a stimulus or stimulus sequence, accuracy of recall improves. With sequences of stimuli, improvement over successive exposures manifests in two parallel changes: (i) a flattening of the serial position curve, and (ii) a decrease in overall error rates. We used a visuomotor sequence-learning paradigm to investigate the extent to which these two changes in visual working memory (VWM) were driven by separable familiarity-induced capacity increases and resolution improvements. Our stimuli consisted of a disk that traversed a trajectory defined by quasi-randomly directed linear motion segments. Forty-four participants (from four experiments) viewed the disk's motions multiple times, and, after each such presentation, used a graphics tablet and stylus to reproduce the disk's path from memory. Reproductions were recorded for offline analysis of the error made in reproducing each segment. The analysis confirmed that, as in other sequence-learning tasks, participants' error magnitudes showed a strong serial position curve on first seeing each sequence, which flattened with subsequent presentations; the flattening was accompanied by an overall increase in accuracy. For a finer-grained analysis, we created error distributions for each combination of segment serial position, participant and stimulus repetition. Then, for each distribution, we found the best-fitting Gaussian + uniform mixture model. The serial-position dynamics associ-

ated with the model's two parameters revealed that the flattening of the serial position curve arose primarily from improvement in VWM's resolution, which quickly reached ceiling (after two or three presentations). In contrast, the continued overall decrease in error magnitude came from a change in VWM capacity, which slowly approached 100% of the segments being in memory. The differing dynamics of representation accuracy and capacity limits suggest that learning-induced improvements in working memory depend on two separable sources of improvement.

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54.15, *3:30 pm*

The volatility of working memory

Daryl Fougnie[1](darylfougnie@gmail.com), Jordan W. Suchow[1], George A. Alvarez[1]; [1]Department of Psychology, Harvard University

Working memory, the ability to retain task-relevant information in an accessible state over a brief span of time, is strikingly limited. Models of working memory explain these limitations by postulating a finite resource that is divided among stored items in a continuous or quantized manner, and they assume that the quality of memory representations is determined solely by the number of items that the resource is spread among, being otherwise fixed for each individual. Here, we consider the possibility that the precision of a memory is not fixed within an individual, but varies across reports. We model performance on a standard working memory task where participants are asked to remember the colors of a set of colorful dots, and then after some delay, to report the color of a dot selected at random (e.g., Zhang & Luck, 2008). In the fixed-precision model, the participant either remembers something of the probed dot, in which case errors are normally distributed with fixed precision centered on the true color, or remembers nothing about the item and guesses blindly, in which case errors are distributed uniformly. In our variable-precision model, precision itself varies across reports and is normally distributed. We found that the variable-precision model produced a significantly better fit than the fixed-precision model for each participant. Additional experiments found that this variability cannot be explained by variation in state-based fluctuations in attention or arousal, by uneven allocation of a finite resource, or by differences in the color or position of tested items. Instead, there appears to be substantial variability in the precision of representations, which is inconsistent with the assumptions of existing models of working memory capacity, including both slot- and resource-based models. We propose a new framework in which representational variability arises from stochastic processes that play out independently across representations.

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54.16, *3:45 pm*

Variability in encoding precision accounts for the limitations of visual short-term memory

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The question whether visual short-term memory (VSTM) consists of a fixed number of discrete chunks or of a continuous resource has been intensely debated. Recent work suggests that only the former model can explain human performance, in particular the observed increase in guessing with set size. However, continuous-resource models have not taken into account that the amount of resource per item may vary across items and trials, for example due to attentional fluctuations. We developed a new model that incorporates this variability. In this model, the encoding precision of a stimulus decreases on average inversely proportionally to set size but is variable around this average. We tested this variable-precision model against leading previous models in three experimental paradigms: delayed estimation (recall), change detection, and change localization. We performed each experiment for both orientation and color. In the change detection and change localization experiments, we varied not only set size, but also the magnitude of change and stimulus reliability. Across all six experiments, the variable-precision model provided excellent fits to the data, accounted for the increase in guessing, and outperformed the other models in a formal comparison. Furthermore, we found that the variable-precision model can readily be implemented using an existing neural architecture, namely the divisive normalization model of attention (Reynolds and Heeger). We modified this model to incorporate attentional fluctuations and stochasticity in spike generation. With these modifications, the neural network can quantitatively reproduce subjects' behavior in delayed estimation, despite not containing any limit on the number of items kept in memory. The neural model is consistent with extant physiological findings. Together, these results provide strong converging evidence – both behavioral and neural – that VSTM resource might not be discrete and fixed, but continuous and variable. The variable-precision model might provide a unifying framework of attention and working memory.

54.17, *4:00 pm*

"Event type" representations in vision are triggered rapidly and automatically: A case study of containment vs. occlusion

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Recent infant cognition research suggests that the mind reflexively categorizes dynamic visual input into representations of "event types" (such as occlusion or containment), which then prioritize attention to relevant visual features - e.g. prioritizing attention to the dimension (height vs. width) that predicts whether a rectangular object will fit inside another in the context of containment, but not occlusion, even when those events are highly visually similar. We recently discovered that this form of "core knowledge" continues to operate in adults' visual processing: using a form of change detection, we showed that the category of an event dramatically influences the ability to detect changes to certain features. In the current study we explored just how event type representations may be quickly and flexibly triggered by specific visual cues. Subjects viewed dynamic 2D displays depicting repeating events wherein 5 rectangles oscillated horizontally, moving either behind or into 5 horizontally-oriented and haphazardly placed containers. Occasionally, a rectangle changed its height or width while out of sight, and observers pressed a key when they detected such changes. Detection was better for height changes than for width changes in containment events, but not in occlusion events (since height predicts fit in horizontal containment events). This was true not only when each individual rectangle always consistently underwent occlusion or containment, but also when each rectangle randomly underwent occlusion or containment during each oscillation. We also independently varied containment vs. occlusion for the disappearance and reappearance of the rectangles, and discovered that enhanced change detection for the "fit"-relevant dimension only occurred when containment cues were present for both the disappearance and reappearance. Collectively, these and other results indicate that event-type representations are formed and discarded during online visual processing in response to cues that may change from moment to moment.

54.18, *4:15 pm*

Homologous mechanisms of visuospatial working memory maintenance in macaque and human: Properties and sources

Robert M.G. Reinhart[1](robert.reinhart@vanderbilt.edu), Richard P. Heitz[1], Braden A. Purcell[1], Pauline K. Weigand[1], Jeffrey D. Schall[1], Geoffrey F. Woodman[1]; [1]Department of Psychology, Vanderbilt Vision Research Center, Center for Integrative & Cognitive Neuroscience, Vanderbilt University, Nashville, Tennessee

Although prefrontal and frontal cortex are thought to be critical for maintaining information in visuospatial working memory, the event-related potential index of maintenance is found over posterior cortex in humans. In the present study, we reconcile these seemingly contradictory findings. Here we show that macaque monkeys and humans exhibit the same posterior event-related potential signature of working memory maintenance that predicts the precision of the memory-based behavioral responses. Next, we concurrently recorded intracranial local field potentials from prefrontal and frontal cortical areas to determine their contribution to the event-related potential index of maintenance. The local fields in prefrontal and frontal areas, but not the cortex immediately posterior, exhibited amplitude modulations, timing, and relationships to behavior indicating that they contribute to the surface potentials. These findings show that a distributed neural network, including prefrontal and frontal areas, underlies the event-related potential index of visuospatial working memory maintenance.

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Object recognition: Categories

Tuesday, May 15, 2:30 - 4:30 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Talia Konkle

54.21, *2:30 pm*

Neural Representations of Object Categories at Multiple Taxonomic Levels

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PROBLEM STATEMENT: Objects can be described at multiple taxonomic levels; i.e. Fluffy is simultaneously a tabby, a cat, an animal, and a living organism. Yet, some descriptions are more basic than others (in this case: 'cat') in that they are generated first and maximize within-category similarity (Rosch 1976). Despite numerous behavioral findings confirming this observation, very little is known about the neural representation of objects with respect to different taxonomic levels. METHODS: We address this question with an fMRI study in which subjects passively view stimuli from 32 subordinate-level categories grouped into 4 basic-level categories (8 breeds of dogs, 8 types of planes, 8 types of flowers, 8 types of shoes). ANALYSIS AND RESULTS: We restrict our analysis to early visual areas and object-, scene-, and face-selective areas: V1, V2, VP, V4, LOC, TOS, PPA, RSC, FFA. Dissimilarity matrices based on patterns of fMRI activity (Kriegeskorte et. al. 2008) were computed for our 32 stimulus categories. Interestingly, clear clusters corresponding to basic-level categories do not emerge until V4, LOC, and TOS. However, a correlation classifier could decode categories at the basic-level well above chance for all 9 areas considered, with LOC and TOS approaching 90% accuracy (chance is 25%). In fact, our basic-level classifier performs above chance in all areas even when it is trained and tested on disjoint subsets of subordinate categories. Decoding at the subordinate level, however, was considerably poorer even when controlling for sample size bias between the two levels of classification. SUMMARY: Although information regarding basic level category is present throughout visual cortex, activity patterns within a basic-level category are most similar in later visual areas. Moreover, our results indicate that the basic-level is privileged over the subordinate level, in accordance with Rosch's view, and this representation is most saliently identified in LOC and TOS.

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54.22, *2:45 pm*

Category learning causes long-term changes to similarity gradients in the ventral stream: A multivoxel pattern analysis at 7T

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Category learning causes acquired distinctiveness, selective enhancement of visual discriminability along category-relevant object dimensions. We previously used 3T fMRI adaptation to show that acquired distinctiveness measured behaviorally is accompanied by acquired distinctiveness in object-sensitive regions in the left ventral stream. Here, using high-resolution 7T fMRI, we use multivoxel pattern analysis (MVPA) to show long-term acquired distinctiveness in the ventral stream. Subjects were trained over several days to categorize objects created from a two-dimensional morphspace according to a particular category boundary. Immediate behavioral testing revealed a post-training advantage for discriminating stimulus pairs differing along the relevant dimension compared to the irrelevant dimension; this behavior advantage persisted for well over a week. A day or more after initial category learning, subjects were scanned at 7T while they performed a task requiring them to attend to stimulus location rather than stimulus shape. Voxel pattern similarity was measured in object-sensitive ROIs using a support vector machine (SVM) MVPA. The SVM was trained to classify stimulus-elicited voxel patterns according to the relevant category boundary learned by the subjects or the orthogonal, irrelevant, boundary. Probability of classifying patterns as the SVM's target category decreased monotonically from the most ideal member to the most ideal non-member. In the left LOC, the similarity gradient was steeper when objects differed along the relevant compared to the irrelevant dimension, showing that category learning can selectively sensitize relevant aspects of shape variation in LOC. This study is the first to assess long-term changes to similarity gradients in the ventral stream along relevant vs. irrelevant object dimensions and the first to use MVPA at 7T to show neural signatures of acquired distinctiveness following category learning.

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54.23, *3:00 pm*

Fast Access to Category Level Representations Can Be Dissociated From Perception

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Visual perception has traditionally been explained in terms of feed-forward processing. Demonstrations of ultra-rapid categorization (e.g., Thorpe, et al., 1996) have been interpreted in terms of feedforward processing because responses seem too fast (120–150 ms) for feedback to play a role. But is ultra-rapid activation sufficient for perception? An alternative is that representations of many objects potentially present in a display are activated in a feedforward processing pass; then a subset is selected for perception. We investigated whether fast categorization of familiar versus novel silhouettes is slowed when another familiar object is potentially present in the scene but is rejected by perceptual organization processes. On each of 80 trials, we showed subjects two silhouettes, one familiar and one novel, one above and one below fixation, and asked them to saccade to the location of the familiar silhouette as quickly as possible. Familiar silhouettes portrayed nameable everyday objects. Half of the novel silhouettes were experimental silhouettes, with portions of familiar objects suggested but not perceived on the outside of their borders. Critically, the outsides appeared to be shapeless grounds, as did the outsides of the other half of the novel silhouettes that did not suggest familiar objects there (control silhouettes). Correct saccades to familiar silhouettes were significantly slower when an experimental rather than a control novel silhouette was concurrently in the display (311 ms vs. 293 ms, $p < 0.01$), even though participants were unaware of more than one familiar stimulus. These results show that activation of familiar objects that are potentially present in a scene, but are pruned by perceptual organization processes can affect fast categorization responses. Thus, fast access to category knowledge is not sufficient for perception. These results fit with models that assume a first pass of processing produces broad activation, but that integrative processing is necessary for perception.

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54.24, *3:15 pm*

Brain activity shows that mammals are more animate than reptiles and bugs

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Neuroimaging studies have shown that viewing animate objects like people and animals evokes stronger activity in posterior superior temporal sulcus (pSTS) and lateral fusiform gyrus than does viewing inanimate objects, whereas viewing inanimate objects evokes stronger activity in medial fusiform and lingual gyri and inferior lateral temporal lobes. Less is known about representational structure within the domain of animate categories, for example how different animals are represented. Using fMRI we recorded brain activity (N=11) associated with viewing 12 animal species -- 4 each from mammals, reptiles, and bugs. Using a novel technique for identifying shared representational structure that involves clustering searchlight-defined dissimilarity matrices, we defined regions of interest that included lateral and ventral occipito-temporal cortex, which we refer to as lateral occipital complex (LOC). We used multivariate techniques including pattern classification and similarity structure analysis to explore representation within this region. Classification accuracies were highly significant across subjects for within and between class discriminations. Similarity structures in LOC were highly reproducible across subjects with average correlation between subjects of $r = .81$. Multidimensional scaling revealed a dimension spanning from mammals to reptiles to bugs as a common axis across subjects. The projection of the primary MDS dimension onto the beta weights for the animal categories reveals greater activity for mammals than for bugs in lateral fusiform and pSTS, and greater activity for bugs than for mammals in medial fusiform and lateral inferior temporal cortex. The mammals, which are both subjectively and biologically closer to humans, produced activity similar to that associated with viewing animate objects, while bugs, which are subjectively and biologically distant from

humans produced patterns similar to those for inanimate objects. These findings suggest that animal categories fall along a continuum in representational space that is predictable by the degree of animacy exhibited by each category.

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54.25, *3:30 pm*

Comparing Animacy and Real-World Size Object Topography In Occipito-Temporal Cortex: a "Coarse MVPA" approach

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Animate and inanimate objects evoke large-scale differential responses across occipito-temporal cortex; the same has been shown for objects of big and small real-world sizes. How are these two orthogonal object dimensions represented across the cortex? Images of big animals, big objects, small animals, and small objects were presented in a blocked design to 12 participants undergoing functional neuroimaging. We used a "coarse MVPA" approach to examine the large-scale spatial distribution of responses across occipito-temporal cortex. 20 spherical regions-of-interest were arrayed across parahippocampal, fusiform, lateral occipital, and medial occipital cortex. Along this continuous band of cortex, the animacy organization had 7 alternating peaks (4 for animals>objects; 3 for objects>animals), while the size organization had 3 alternating peaks (2 for big>small entities and 1 for small>big entities). The animacy and size peaks were arranged as follows: (i) medial big animal regions, (ii) adjacent big object regions (ii) adjacent lateral animal regions with no size modulation, and (iii) a small object region at the center. At the two medial extremes, we found novel animate regions, located even more medially than scene-selective regions; these were only elicited by big animals, demonstrating an interaction between the size and animacy organization. Pattern analyses revealed that the animal/object organization was substantially stronger than the big/small organization (shared animacy: $r=.56$; shared size: $r=-.68$; $t(11)=10.5$, $p<0.001$), and that objects were more differentiated by size than animals ($t(11)=4.7$, $p<0.001$). Overall these results demonstrate that (i) the medial-to-lateral responses of objects vs animals along the ventral surface are part of an even larger-scale alternating organization, and (ii) big vs small differences apply more strongly within the inanimate domain. The topography of these responses are reminiscent of horizontal and vertical meridian alternations in early visual cortex, and thus may potentially be used to define different areas of high-level object cortex.

54.26, *3:45 pm*

Investigating the relationship between visual object category selectivity measured with functional neuroimaging and electrocorticography in the human ventral temporal cortex

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Functional neuroimaging (fMRI) is commonly used to investigate the organization of human visual cortex. Previous reports described category-selective (e.g. faces, bodyparts, houses) fMRI activations in consistent locations of the occipitotemporal cortex. Similar selectivity has also been reported using electrocorticography (ECoG). However, the precise relationship between the signals measured with fMRI and ECoG is not well understood. To address this issue, we measured category selectivity to faces, bodyparts, cars and houses using fMRI and ECoG in seven patients undergoing epilepsy surgery evaluation. ECoG signals from electrodes located on ventral temporal cortex were analyzed both by computing event-related potentials (ERP) and broadband power in the gamma range (70-200 Hz). The latter is correlated with mean population firing rate (Manning et. al. 2009) and linked with fMRI signals (Mukamel et al., 2005). Our analyses indicate that (1) category selectivity exhibited in ERP and gamma signals largely overlapped although not completely, suggesting these signals reflect partially distinct neural processes, (2) ECoG selectivity for faces was usually stronger than that measured with fMRI and (3) ECoG bodypart selectivity often spatially overlaps with face selectivity, with the former delayed by 30-50ms relative to the latter. Preliminary co-localization analyses reveal an overlap between the selectivity measured in fMRI and ECoG to faces, bodyparts and houses at the single subject level. Specifically, category-selective ECoG responses were often recorded at electrodes overlapping or near fMRI activations of the same selectivity. Co-localization was best for faces, probably due to the location of face activations on a gyrus (fusiform), relative to activations for houses and bodyparts that are located in a sulcus (collateral and occipitotemporal, respectively), and consequently further away from electrodes recording ECoG signals. Our results thus indicate an overall tight coupling between category selectivity measured with fMRI and electrophysiology, within the same subject in human occipitotemporal cortex.

54.27, *4:00 pm*

Neural Representation of Human-Object Interactions

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Identifying the relationships between objects in a scene is a fundamental goal in scene understanding. It is known that two interacting objects are perceptually grouped (Green & Hummel, 2006), and that interacting objects evoke greater activity in the lateral occipital complex (LOC) compared to noninteracting objects (Kim & Biederman, 2011). However, critical questions remain about the neural representations of interacting objects. Do object-sensitive regions such as LOC actually encode interactions between objects? How do scene-sensitive regions such as the parahippocampal place area (PPA) respond to simple two-object interactions? In our fMRI experiment, subjects performed a one-back task while viewing three types of images: humans and objects in isolation, a human and object overlapping without a meaningful interaction, and a human interacting with an object in a familiar way. We then used MVPA methods to determine which regions are sensitive to the meaningful interactions. We have obtained preliminary results from an experiment investigating two types of human-object interactions: riding a horse and playing a guitar. For each subject, we trained a classifier to discriminate between the responses to the object pairs person+horse and person+guitar, and then tested our classifier on a held-out run. We find qualitatively different results in object-sensitive areas and scene-sensitive areas. In LOC, both interacting and noninteracting object pairs can be decoded with similar accuracies. In PPA, however, decoding was better for interacting that noninteracting objects, despite the fact that both conditions contain the same human/object pairs. These results suggest that PPA's sensitivity to scenes extends to a simple interaction of a single human and object, whereas LOC can represent object pairs regardless of whether the objects are interacting in a meaningful way or not.

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54.28, *4:15 pm*

Early visual areas recruited in automatic contextual processing of words

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Objects do not appear randomly in our environment, but rather clustered in typical contexts. For example, an oven will likely appear with a refrigerator and a microwave in close proximity. Previously, the parahippocampal cortex (PHC), the retrosplenial complex (RSC), and the medial prefrontal cortex (MPFC; Bar & Aminoff, 2003) were designated in the neural mechanism underlying contextual processing by comparing BOLD activity elicited when viewing pictures of objects with strong contextual associations (e.g., shower) with activity elicited when viewing pictures of objects with weak contextual associations (e.g., folding chair). This neural mechanism was defined in various experiments using only pictures, and it was unclear whether these regions would also respond when viewing words with strong contextual associations. To explore this, twenty participants evaluated 360 words for contextual strength. Based on these results, words were delineated as having a strong context or a weak context. In a separate experiment, ninety-five participants performed a recognition memory test, unrelated to contextual processing, on these 360 words while undergoing fMRI. BOLD activity was compared when viewing words with strong con-

textual associations (e.g., bullet) with words with weak contextual associations (e.g., fountain) while performing the memory test. In efforts to isolate contextual processing, other factors such as concreteness, imageabiity, memory condition, frequency, familiarity, number of letters, etc., were used as regressors in the model. As hypothesized, words with strong contextual associations elicited greater activity in the PHC, RSC, and MPFC. However, we also observed significant differential activity in early visual areas between strong and weak context words that were equated on concreteness and imageability. We posit that this unexpected finding reflects automatic, contextually-driven processing which provides feedback to visual areas.

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Perception and action: Decisions

Tuesday, May 15, 5:30 - 7:00 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Brett Fajen

55.11, *5:30 pm*

Rhythmic fluctuations in evidence accumulation during decision making in the human brain

Valentin Wyart[1](valentin.wyart@gmail.com), Vincent de Gardelle[1], Jacqueline Scholl[1], Christopher Summerfield[1]; [1]Department of Experimental Psychology, University of Oxford

Categorical choices are preceded by the accumulation of sensory evidence in favour of one action or another. Current decision-making models assume that momentary evidence is integrated continuously over hundreds of milliseconds in the form of a decision variable, a quantity that maps the accumulated evidence onto an appropriate action. However, the notion that evidence accumulation occurs at a constant rate is inconsistent with a rich psychological literature describing how human perception is limited by a central bottleneck, giving rise to cognitive blinks of few hundreds of milliseconds during which sensory information is perceived as lagging or even missed. During perceptual categorisation, we found that both the encoding of momentary evidence in human EEG signals and its impact on choice were modulated rhythmically by the phase of ongoing delta oscillations at 2 Hz over the parietal cortex. By contrast, fluctuations in beta-band activity (10-30 Hz) over the motor cortex encoded the accumulated evidence as a response preparation signal. These findings draw a clear distinction between a central stage at which momentary evidence is weighted, and a motor stage at which the accumulated evidence is mapped onto action. They also suggest that the attentional bottleneck identified as responsible for cognitive blinks might impose a cyclic sampling constraint on evidence accumulation, with successive samples competing for limited processing capacity before being integrated.

55.12, *5:45 pm*

An oculomotor trace of implicit perceptual predictions

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Background: Making predictions and monitoring their accuracy is considered a fundamental aspect of the brain, implicated in motor control, perception and cognition. Evidence for predictive processing in perception includes among others the dependency of response times on prior events. Here we report a surprising reflection of implicit perceptual predictions in the pattern of oculomotor response to a sequence of events. Method: During fixation observers viewed and silently counted sequences of 100 randomly ordered small visual patterns of two types, flashed at 1 Hz repetition rate. The visual pattern pairs consisted of high and low contrast Gabor patches (contrast condition), red and blue circles and triangles (color and shape conditions) and rectangles above or below fixation (position condition). Eye-tracking at high-speed was applied and the average latency of the first microsaccade in a time window following stimulus onset was computed. Results: In all conditions, microsaccade inhibition typically lasted for 300-500 ms after stimulus onset as previously reported, but depended on the former 4-5 stimuli. Repetition (e.g. red after a sequence of reds) shortened the inhibition (speedup), while a change (e.g. blue after a sequence of reds) increased the inhibition (slowdown). The magnitude of the effect was 5-10 ms per item, 50-100 ms overall. Preliminary results indicate a diminished effect when stimuli were presented in a regular (repetitive) order, suggesting a high-level predictive process. Conclusion: Microsaccades are inhibited for a duration that depends on the history of preceding perceptual events. We describe this dependency in terms of a simple model that computes the likelihood of future events based on the recent past, assuming longer microsaccade latency for surprise. The current oculomotor measure of implicit perceptual predictions could be applied to non-communicating individuals.

55.13, *6:00 pm*

Dual tasks affect movement latency but not movement time during rapid pointing

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While there is evidence that attention is deployed to a movement goal, it is not clear how deployment of attention changes with task demands or how it affects movement outcomes. We investigated the structure of attentional resources during rapid pointing with a dual-task paradigm. Each component of the dual-task was tested separately to establish baselines, enabling comparison of single and dual-task conditions. The perceptual task was an alphanumeric search task presented at central fixation. The target was a letter embedded within a letter string. The goal-directed movement consisted of a rapid point made to a touchscreen. The target was a small, high contrast dot presented briefly (100ms) at 4 or 8° eccentric to central fixation at one of 8 possible locations with equal probability. The dual-task conditions differed only in when the search task ceased, either at pointing stimulus onset (part reach), or after reach completion (whole reach). At the end of each trial, participants reported how many times the target letter was presented. We measured endpoint accuracy and precision, movement latency and movement time and search task performance. Dual-task conditions generally negatively affected search task performance, indicating a degree of shared resources during movement planning and perception, consistent with previous results. The greatest decrease in performance was observed between baseline and whole reach conditions, indicating that ending the search task during movement planning (part reach) had less impact on search performance than task continuation. Pointing accuracy and precision were not significantly different between conditions. Movement latency increased in the dual-task conditions, while there was no significant difference in reach times. Results suggest there is a cost to reach performance if attention is engaged away from the reach goal but this cost is associated with movement planning rather than execution.

55.14, *6:15 pm*

The development of visuomotor decision making under risk

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Human adults appear to take their sensory and motor uncertainty into account in order to maximize gain in visuomotor decision tasks that pose challenges similar to those involved in catching a rapidly approaching ball or reaching for an object while avoiding another. How this ability develops is currently not known, but it is possible that immature visuomotor decision-making with respect to risks can help explain the high rate of childhood accidents. To explore the development of visuomotor decision making under risk, we applied a recently proposed economic decision making framework that describes adults' behavior in a rapid pointing task (Trommershäuser et al., 2003) to a child-friendly version of the same task. We asked 6 to 11-year old children and adults to earn points by rapidly touching a target on a screen, while avoiding a partially overlapping penalty region. Values assigned to penalty and target regions and spatial configurations of those regions were varied. To correctly choose the aiming point that maximizes gain for each condition, subjects must combine information about the reward structure with information about their own visuomotor uncertainty. In line with previous findings, adults chose movement strategies that came close to maximizing expected gain in response to changes in penalty location and size. Children, however, showed a change in strategy when risk was introduced but their pointing strategies were less close to optimal than those of adults. We used two control tasks to check that children's performance was not confounded by either non-linear understanding of numeric value or poor knowledge of own motor variability. Our findings suggest that the ability to take visuomotor uncertainty into account when maximizing gain in a rapid visuomotor task takes a surprisingly long time to develop, and continues to mature until after age 11 years.

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55.15, *6:30 pm*

Failure is unavoidable: The effects of reward, reward-learning and penalty on rapid reaching

Craig Chapman[1](c.s.chapman@gmail.com), Jason Gallivan[2], Jim Enns[1]; [1]Psychology, University of British Columbia, [2]Psychology, Queen's University

Stimuli that are highly predictive of reward or loss in one context are readily associated with privileged perceptual processing in other contexts (Raymond & O'Brien, Psych Science 2010). Here we study how these associations extend to the dorsal stream's automatic pilot (Chapman & Gallivan et al, Cognition 2010; Pisella et al, Nature Neuroscience, 2000). In previous work, we have shown that participants forced to begin reaching before they know the final target position show movement trajectories that are biased toward the side of space containing a greater number of targets, up to a limit of about four (Gallivan & Chapman et al, Psych Science, 2011). Using the same task in the current study, participants made rapid reaches toward displays with two differently shaped targets. Each target shape was associated with a specific gain or loss in a preliminary learning task (Experiments 1 & 2) or the shape-specific gain or loss association was acquired during the rapid reach task (Experiments 3 & 4). The design of our experiments allowed us to explore the independent consequences of reward value (gain vs. loss) and reward probability (low vs. high) on the movement trajectories. We show that reaches are automatically biased toward both stimuli with a positive reward-value and stimuli with a high probability of being acted upon. Conversely, we find no evidence that reaches are biased away from (or toward) stimuli with a negative reward-value. This indicates that target selection and inhibition in non-conscious motor planning are not symmetric – the automatic pilot is much faster to select targets (especially those of high value) than it is to inhibit non-targets (even if moving toward them leads to a negative outcome). In essence, the automatic pilot cannot avoid what is not good for it. For that, the more deliberate processes of the frontal lobes are likely involved.

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55.16, *6:45 pm*

Humans exploit the biomechanics of bipedal gait during visually guided walking over rough terrain

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When walking over flat terrain, humans achieve remarkable energetic efficiency by exploiting the passive mechanical forces inherent to the biomechanical structure of bipedal locomotion. The idea that energetic efficiency is achieved by exploiting passive forces in the body has gained traction in the field of biomechanics, but no research exists on the way these principles govern the control of walking when vision is needed to guide foot placement. We tested the hypothesis that when walking over rough terrain, vision is used to identify footholds that allow the walker to approximate the efficiency of walking over flat terrain. Subjects walked over an array of randomly distributed virtual obstacles that were projected onto the floor by an LCD projector while their movements were recorded using a full-body motion capture system. Walking behavior was analyzed during a full-vision control condition as well as in a number of other visibility conditions in which obstacles did not appear until they fell within a window of visibility centered on the moving observer. Analyses focused on the relationship between the size of the visibility window and the active (i.e., muscle-generated) forces needed to redirect the center of mass to avoid stepping on obstacles. When the visibility window restricted vision to less than two steps, additional energetically costly active muscular forces were needed to avoid obstacles. When the visibility window allowed vision beyond two steps, active forces dropped to baseline levels observed in the full-vision condition. The findings suggest that visual information from the immediate foreground is used to identify footholds that allow the walker to approximate the energetic efficiency realized when walking over uncluttered terrain. The theoretical framework provided by the dynamic walking approach to gait control suggests an elegant explanation of the functional significance of the two-step distance in the visual control of human walking.

Acknowledgement: NIH 1R01EY019317

Spatial vision: Neural mechanisms

Tuesday, May 15, 5:30 - 7:00 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Luke Hallum

55.21, *5:30 pm*

Retinally stabilized stimulation reveals mismappings between retinal and perceived location

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In the human fovea, retinal wiring shows low or no neural convergence, such that the excitation of single photoreceptor cells is mapped to the receptive field of single ganglion cells. Outside the fovea, a one-to-one wiring is replaced by a less precise retinotopic mapping and increased convergence. As a result, mismappings between the exact retinal location and the corresponding receptive fields may exist. In normal viewing, however, the contribution of these mismappings might be obscured by a constantly moving and thus spatio-temporally averaged retinal image. We here employ an adaptive optics scanning laser ophthalmoscope (AOSLO) with real-time motion tracking to deliver visual stimuli at high levels of retinal contingency. In a vertical three-dot hyperacuity task, subjects had to adjust the position of the central dot (2 arcmin square) to be collinear with the two flanking dots. Under retinally stabilized viewing conditions we find local point of subjective equality (PSE) biases that differ depending on retinal location. As an example, along a 10 arcmin strip of retina, 0.6 deg from the fovea, PSE bias changes were as large as 30 arcsec, roughly equaling the diameter of a single cone at that retinal location. The results suggest that vernier alignment under retinal stabilization can be used as a tool to discover minute retinal mismappings, and help to characterize the discrete retinal wiring underlying extra-foveal vision. The AOSLO is also able to reliably position stimuli on target cones over many months such that it will be possible to track biases over time to see if they change as a result of visual experience.

Acknowledgement: WMH supported by DFG and NIH

55.22, *5:45 pm*

Mechanisms of selectivity for orientation-defined form in macaque visual cortex

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Humans perceive texture-defined form in a way that suggests that second-order stimuli are encoded by mechanisms computing a localized difference of orientation signals like those arising from V1 neurons responding to conventional luminance gratings. Those responses can be modulated by optimally and orthogonally oriented contrast falling in or near the receptive field (RF) center. One model for second-order processing relies on the orientation tuning and the spatial organization of RF center-surround modulation to create selectivity for form. We tested this model by measuring the responses of 25 single units in V1 and V2 of opiate-anaesthetized macaques. We stimulated neurons with summed contrast-modulated (CM) gratings covering both the RF center and surround. CM grating 1 was a sinusoid of optimal spatial frequency, orientation, and drift rate. CM grating 2 was similar, but of orthogonal orientation. Each grating was independently contrast-modulated across 6 drift directions and 5 spatial frequencies. The responses of most neurons were modulated by both optimally and orthogonally oriented contrast. Suppression arose from optimally and orthogonally oriented contrast that was similar in its overall magnitude, but different in its spatial organization, thus conferring second-order selectivity to responses. For both optimally and orthogonally oriented contrast, we used the difference of an excitatory and a suppressive Gaussian to model this organization. In many modulated cells, optimally oriented contrast suppressed responses when it appeared in a surround that was organized anisotropically relative to the RF center. Orthogonally oriented contrast typically suppressed responses when it was coextensive with the RF center. Selectivity for second-order form may not depend on dedicated "second-order neurons" that collect orientation-selective signals from V1 neurons.

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Rather, selectivity may arise by spatially organized, orientation-selective interactions that modulate the response of the RF center to conventional luminance gratings.

Acknowledgement: NIH EY04440, NH&MRC 1016388

55.23, *6:00 pm*

Avoiding biases in estimating cortical reorganization using fMRI population receptive field mapping

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Purpose: The population receptive field approach (pRF) 1 provides an estimate of the region of visual space that best excites each fMRI voxel. Recently there has been increasing interest in using the pRF method to examine cortical reorganization resulting from vision loss2. Here, we tested the validity of the pRF method in four normally sighted subjects under conditions that simulated a retinal lesion. Methods: We measured BOLD responses to bars drifting in random directions stimulating the central 15 deg of the visual field1 or with the central 3 deg masked, simulating a foveal scotoma. We analyzed the data in two ways. In the 'full visual stimulus' condition we used the full unmasked stimulus as the input into the pRF model, as is currently the standard procedure. In the 'retinal lesion stimulus' condition we used the masked stimulus as input into the pRF model. Results: Using the 'full visual stimulus' analysis method, voxels with pRFs that fell within or near the edge of the scotoma were shifted peripherally, even in voxels with relatively low fit errors (there was no systematic bias in receptive field size). However, this 'apparent rapid re-organization' completely disappeared when analyzing the same data using the 'retinal lesion stimulus' method. A model simulation similarly found that the peripheral shifts observed with the 'full visual stimulus' analysis can be explained purely in terms of biases in the pRF fits, without any underlying cortical reorganization. Conclusion: It is possible to accurately measure pRFs under condition of vision loss, if and only if pre-cortical visual losses are taken into account. 1Dumoulin SO, Wandell BA. NeuroImage. 39(2): 647-660 (2008). 2Baseler HA et al. Nature Neuroscience. 14: 649–655 (2011).

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55.24, *6:15 pm*

Retinotopic mapping in a patient with optic chiasm compression: converging evidence from visual field testing and fMRI

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Introduction: Visual information from the temporal hemifield of each eye crosses the optic chiasm before innervating the optic tracts. Compression of the chiasm by pituitary tumors may restrict the information flow, causing bi-temporal visual field deficits. Successful tumor removal largely reestablishes axonal conduction, which makes this condition a useful model for studying the effects of reversible, long-term visual deprivation. Here, we investigate the time-course of visual recovery following removal of a pituitary tumor using behavioral and functional magnetic resonance imaging (fMRI) methods in a case study. Method: The patient (age 63) had a pituitary tumor removed following severe chiasmal compression. She was tested three times: prior to surgery, one month and two months after surgery. All tests were performed monocularly on the eye showing the greatest initial visual field deficit. Visual field deficits were assessed at each time point. Retinotopy was measured by presenting arcs to one of two locations within each field quadrant (3º and 5º eccentricity). Mapping stimuli were either isoluminant, low or high contrast. Isoluminance was determined within the scanner using a flicker fusion task. Results: Following tumor removal, we observed a rapid recovery of visual function, as well as corresponding retinotopic reactivation of early visual areas. Conclusions: We report a rapid time course of visual recovery following prolonged (partial) visual deprivation. A close correspondence was observed between fMRI (retinotopy) and standard field tests. Additional analysis of retinotopy with low-contrast and isoluminant stimuli will allow us to determine whether pituitary tumors preferentially compress a given class of nerve fibers (i.e., parvocellular vs. magnocellular).

55.25, *6:30 pm*

Contributions of fixational eye movements to the early encoding of visual information

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In the periods in between saccades, humans and other species continually perform microscopic eye movements. It is known that these movements prevent fading of the image and enhance vision of high spatial frequencies. However, the impact of microscopic eye movements on the signals impinging onto retinal receptors and on the neural encoding of visual information remains unclear. Here, we examine the spatiotemporal stimulus on the retina of human observers while they freely view pictures of natural scenes. We show that the spectral density of the retinal image during normal intersaccadic fixation differs sharply from that of the external scene: whereas low spatial frequencies predominate in natural images, fixational eye movements redistribute the input power on the retina to yield temporal modulations with uniform spectral density over a wide range of spatial frequencies. This finding links the normal instability of visual fixation to the statistics of the natural world: the resulting equalization of power depends on the joint characteristics of the scene and fixational instability, indicating a form of matching between the statistics of natural images and those of normal eye movements. This spatial whitening of the retinal stimulus implies a reduced sensitivity to predictable input correlations and an enhanced response to luminance discontinuities, outcomes long advocated as fundamental goals of early visual processing. In other terms, our results support a contribution from fixational eye movements to the enhancement of luminance edges in neural representations in the retina and thalamus.

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55.26, *6:45 pm*

More than maps: the fMRI orientation signal persists after removal of radial bias

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Many recent studies of the human visual system have made use of multivariate pattern analyses (MVPA) to "decode" feature representations from fMRI activation patterns in the visual cortex. We have previously claimed that such methods are sensitive to signals originating from irregularities in the arrangement of cortical columns, found on spatial scales of millimeters (Kamitani & Tong, 2005; Swisher et al., 2010). Evidence for this claim comes primarily from studies of the representation of visual orientation. However, this interpretation is complicated by the presence of larger-scale anisotropies in the cortical orientation map, such as the oblique effect and radial bias. Accounting for the role that such anisotropies play in orientation decoding has accordingly been a focus of much previous work (e.g. Mannion et al., 2009; Swisher et al., 2010). Recently, Freeman and colleagues (2011) have argued that a large-scale retinotopic preference for radial orientations accounts for the entirety of the signal detected in conventional fMRI orientation decoding. This study found that removal of a radial bias component greatly impaired the accuracy of orientation decoding. Specifically, they found that regressing out a spatial map derived from retinotopic mapping disrupted both orientation decoding and decoding of retinotopic position to an equal degree. Using paradigms similar to those of Freeman et al (2011), we find that the orientation signal is only modestly impacted by removal of retinotopic radial bias. Across a variety of stimulus configurations, we instead find that removal of independently-measured retinotopic components consistently impairs the accuracy of retinotopic decoding significantly more than that of orientation decoding. The presence of a substantial residual orientation signal after removal of retinotopic components is inconsistent with an orientation signal carried exclusively by retinotopic radial bias, as previously claimed. Instead, our results strongly support a sensitivity to millimeters-scale irregularities in cortical feature maps.

Acknowledgement: NIH R01 EY017082, F32 EY019448, P30 EY008126

Tuesday Afternoon Posters

Perceptual learning: Neural mechanisms

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

56.301 MEG slow activity in V1 during sleep and perceptual learning

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Sleep plays a key role in facilitatory effect of memory and learning. However, the underlying neural mechanism has yet to be completely understood. Here, to better clarify the mechanism for the faciliatory effect on visual perceptual learning, we measured fine-scaled spatio-temporal neural activity during sleep after training of texture discrimination task (TDT) using a multimodal neuroimaging technique that combines MEG and MRI. A leading hypothesis suggests that the slow wave activity (SWA) during the sleep period is involved in the facilitatory effect. Since the TDT is associated with changes in the region of the primary visual area (V1) that retinotopically corresponds to the trained visual field quadrant, we tested whether the strength of SWA in V1 is correlated with the facilitatory effect during sleep on TDT. Young and healthy participants underwent an MRI session after 4 nightly MEG sessions including 2 adaptation nights, pre-training sleep, and post-training sleep. Before the post-training sleep, TDT was conducted twice; more training in one visual field quadrant and less training in another quadrant. After the post-training sleep, we conducted a re-test of TDT. Wavelet-transformed MEG during sleep was combined with high-resolution MRI to constrain the current locations to the cortical mantle individually. Based on the retinotopic mapping, we localized the 2 cortical quadrants that retinopically corresponds to the more and less trained visual field quadrants in V1 and measured the strength of SWA in those areas. The results showed that the SWA in the trained V1 was markedly stronger in the post-training sleep compared to the pre-training sleep, and the SWA strength in each cortical quadrant was correlated with the performance improvement in each visual field quadrant. The results suggest the feasibility of the hypothesis that the slow wave activity is involved in the consolidation of TDT during sleep.

Acknowledgement: Supported by NIH (R21EY018925, R01EY015980, R01EY019466, R01AG031941, R01MH091801), NSF (BCS-0964776), NCRR (P41RR14075, S10RR021110) and the Athinoula A. Martinos Center for Biomedical Imaging.

56.302 Neural mechanisms of motion perceptual learning

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Practice substantially improves motion direction discrimination. However, the neural mechanism of this perceptual learning is little understood. We studied this mechanism with functional magnetic resonance imaging before and after training. During training, nine subjects practiced eight daily sessions (9,600 trials total) to discriminate motion directions of two successive random-dot kinematograms at 100% coherence, with the method of constant accuracy at 75% correct. Each of the subjects was trained along one of the following eight directions that started from 22.5° and with an increment of 45°. Before and after training, the subjects' motion direction discrimination thresholds were measured along the directions that were 0°, 30°, 60°, and 90° away from the trained direction. Blood-oxygenation-level-dependent (BOLD) signals were also measured in a 3T Siemens magnet while subjects performed the same motion discrimination task along these motion directions at 75% correct. Behaviorally, training gave rise to 44% improvement along the trained direction, which transferred little to the untrained directions. BOLD signals were analyzed in V1, V2, V3, V5/MT+, posterior as well as anterior intra-parietal sulci (pIPS and aIPS), all of which were sensitive to visual motion. We found that, as a result of training, the BOLD responses in V3 and V5/MT+ to stimuli along the trained direction were reduced as compared to stimuli along the untrained directions. Multi-voxel pattern analysis further showed that the decoding accuracy in aIPS was selectively improved for the trained direction after training. Our analysis at the population level suggests that perceptual learning results in a more efficient representation in the visual cortex and a more accurate read-out in the higher-level cortex for the trained stimuli.

56.303 Perceptual Learning alters Neural Tuning in Large-Scale Fronto-Parietal Brain Networks

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Perceptual Learning (PL - improved perceptual performance following practice) is traditionally viewed as relying on neural sensitivity increases in sensory brain regions. However, recent evidence suggests that PL involves higher-order regions in parietal and frontal cortices. This work focuses on two large–scale brain networks comprising fronto-parietal regions and their neural tuning as PL progresses. 20 Subjects performed an orientation discrimination task on Gabor stimuli over the course of 4 days (data from Kahnt et al. 2011). The first and last days were conducted during fMRI-BOLD imaging (1320 trials), while the second and third day were performed in a mock-scanner (3300 trials). 11 orientations were presented, allowing precise measurements of psychometric performance and orientation tuning functions in brain regions during PL. Performance significantly increased from day 1 to day 4 for all orientations, indicating substantial PL. Concomitantly, we find significant BOLD-response increases in a task-positive network (TPN: Insula, ACC, preSMA) and significant BOLD-response decreases in a task-negative network (TNN: LPC, PCC, vmPFC). BOLD changes in these two networks (but not in sensory areas) correlated with perceptual performance and thus scaled with task difficulty. Comparing the first and last day BOLD-profiles (i.e. PL-related changes) showed that in both networks, tuning functions change from nonlinear to linear and drastically increase their response range for all regions, nearly tripling for the TNN-regions. Our results show that PL encompasses marked influences on neural responses in large-scale brain networks comprising fronto-parietal areas. We show that such regions - often interpreted as reflecting a brain "default mode network" (cf. TNN) - change their task-relevant tuning over the course of PL. These data further strengthen the notion that PL is mostly driven by altering neural responses in higher-order decision regions rather than simply by changing sensory tuning.

Acknowledgement: Deutsche Forschungsgemeinschaft (SFB779, 'Neurobiologie motivierten Verhaltens', TP-A3)

56.304 Roles of inhibitory processes in perceptual learning

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Inhibitory processes are important for retrieving relevant information from related but irrelevant distracters. A well-known manifestation of these processes is retrieval induced forgetting (RIF) in which the act of processing of retrieving some target items from long-term memory sometimes impairs the ability to recall other items related to those targets. Is the inhibitory processes involved in the formation of perceptual learning that is defined long-term enhancement of a visual task? To address this question, we tested whether a trained visual target suppresses other untrained visual targets that are related to the trained targets. We divided 8 directional visual motion stimuli into two categories. The moving dots in a stimulus from one category were all red and those from the other category were blue. Two directions of one category were used for training (Rp+). The untrained motion directions from the same category (same color) are called RP-, and the untrained motion direction of the different category (different color) are called Nrp. The experiment consisted of a training stage of 8 sessions, which was preceded and followed by test stages. During the test and training stages subjects were asked to conduct a coherent motion detection task. The results showed that there was a significant interaction among Rp+, Rp-, and Nrp in the differences between pre-test and post-test

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performances. The learning effect of Rp+ was higher than that of either Rp- or Nrp. Importantly, the learning effects between Rp- and Nrp were marginally different. More specifically, the learning effect of Rp- was lower than that of Nrp. These results suggest that the inhibitory processes suppressed the distracter motion of Rp- to facilitate readout of the trained target moiton of Rp+.

Acknowledgement: EY015980, EY019466, AG031941, MH091801, NSF SMA-0835976, BCS-0964776

56.305 **Visual art training in young adults changes neural circuitry in visual and motor areas**

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Visual artists' expertise comes in part from their rich and precise perception of the world and their ability to translate this perception into controlled actions such as drawing and painting. How might acquiring these abilities be reflected in the plasticity of the brain in young adults? Here we investigate the effects of visual art training on the structure and function of the human brain. Undergraduates were tracked for six months as they took a sequence of intensive courses in painting or drawing. Each month they received high-resolution structural and DTI scans as well as functional scans as they a) made judgments about Craik-O'Brien-Cornsweet and Müller-Lyer illusion stimuli and b) created gesture drawings from observation of human figures. Students taking either organic chemistry or engineering problem solving courses were also tracked and served as non-creative learning and creative learning control groups, respectively. Complementing recent findings by Graham & Meng (VSS 2011) that professional artists demonstrate reduced illusory effects compared to naïve subjects, illusion strength decreased during the study for art students more than controls. Art students also improved in gesture drawing ability, and one month into the study these changes were already accompanied by measurable differences in brain function: illusion strength correlated with BOLD signal in dorsal occipital and posterior parietal areas, and art students showed increased cerebellar activity during the gesture drawing task compared to controls. Gray matter volume, white matter connectivity, and task-related functional connectivity were also investigated. These results suggest that plasticity in the neural circuitry underlying perception and action allows visual artists to develop their skillful observation and manipulation of the environment.

Acknowledgement: Dartmouth College Internal Funding, Templeton Foundation

56.306 **Action Video Games playing improves learning to learn in perceptual learning**

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Playing action video game can substantially improve visual performance. Here we consider the mechanisms that support such improvements. Using the equivalent external noise technique (Lu & Dosher, 1998), we found improved thresholds across a wide range of external noise levels (downward shifts of TvC curves) in Action Video-Game Players (VGPs) as compared to Non-Action Video-Game Players (NVGPs). Both the perceptual template model and a probabilistic neural model (Bejjanki et al, 2011) explain the improved TvC functions in terms of better task-relevant perceptual templates utilized by the VGP group. How does action video game experience improve the quality of the perceptual templates? One possibility is that action video game experience increases general visual sensitivity. If that is the case, the VGP advantage would be present on the very first trial of any visual task, and would not require any training with the task. Another possibility is that action video game experience may result in an increased ability to learn task-relevant statistics. This "learning to learn" view predicts reasonably equivalent performance between groups early on in training of a new visual task, with the VGP advantage appearing and then increasing through experience with the task. To test these hypotheses, VGPs and NVGPs performed a peripheral Gabor orientation identification task in high Gaussian noise. Each subject completed 8 blocks in an initial training phase and then 8 additional blocks in a transfer phase (where both the reference angle and location of the Gabor were changed from the training phase). As predicted by the "learning to learn" account, VGP and NVGP performance was comparable before training.However, as the training proceeded, VGP improved their performance much faster than NVGP, suggesting more efficient learning. Together, these results suggest that action video game play results in enhanced performance by fostering "learning to learn".

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56.307 **Learning-Dependent Changes in Brain Responses While Learning to Break Camouflage: A Human fMRI Study**

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Camouflage represents an extreme case of figure-ground segregation whereby a target object, even when in 'plain view', is difficult to distinguish from its background. Neural mechanisms by which we recognize a camouflaged object, i.e., break its camouflage, are largely unclear. To characterize the neural responses underlying camouflage-breaking, we carried out two human fMRI experiments. The first experiment used a rapid, event-related design in which subjects had to detect a novel 'digital embryo' target camouflaged against a background of a large number of distractor digital embryos (Hegdé et al, JOV 6:677, 2006). We found that the responses in many regions of interest (ROIs), most notably fusiform gyrus (FG) and superior temporal suclus (STS) were significantly larger during those trials in which the subjects (N = 13) correctly reported the presence or absence of a target, compared to the responses during incorrect trials (p <0.05, corrected for multiple comparisons). To assess the extent to which the response patterns are independent of the experimental conditions, we carried out a second experiment using a time-resolved design and stimuli in which the target was a human face camouflaged against uniform background texture. The response patterns of many brain regions, including FG and STS, were similar to those in the first experiment, indicating that the responses were not idiosyncratic to the category of the target object or the nature of the background. On other hand, the BOLD responses in the intraparietal sulcus (IPS) were suppressed below baseline levels during behaviorally correct trials in the second experiment, while the corresponding responses were enhanced above baseline levels in the second experiment. Together, these results suggest, although do not prove, that camouflage-breaking may involve a 'core' set of brain regions that whose responses are largely invariant to the nature of the target and of the background.

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56.308 **Men need a nap to show perceptual learning of motion direction discrimination, but women do not.**

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Sex differences in cognitive performance have been found for explicit memory tasks (Lewin et al. 2001), but few studies have reported sex differences on perceptual tasks. We investigated differences between young men and women in perceptual learning (PL) of a motion direction discrimination task (Rokem and Silver 2010) using a nap paradigm (Mednick et al. 2003). At 9AM, thresholds were obtained for two directions of motion, followed by 40min of training on one of those two directions of motion. Subjects were classified into one of two groups: nap (60-90 min; with polysomnography) and no-nap. At 4PM, thresholds were reassessed for the trained and untrained directions of motion as well as a direction of motion that was not previously tested. Men who napped (n=28) showed increased learning of the trained direction of motion relative to men who did not nap (n=25) and no learning of the untrained or novel motion directions in either the nap or no-nap conditions. In contrast, women in both the nap (n=42) and no-nap (n=28) conditions showed significant learning of both the trained and untrained motion directions. Women also showed learning for the novel motion direction following a nap, compared to no-nap. In conclusion, extending previous studies (Mednick et al. 2003, 2005), we found that short naps play an important role in the consolidation of PL in motion perception but that this effect is specific to men. Men required sleep to show learning of a trained motion direction, whereas women performed equally well after either wake or sleep. Additionally, men who napped showed high direction specificity for learning of the trained motion direction, whereas women who napped exhibited generalized learning to the untrained and novel motion directions.

Acknowledgement: NIH K01MH080992

56.309 **Pharmacologically enhanced naps modulate perceptual learning and verbal memory**

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A central function of sleep is the consolidation of memories (Mednick et al. 2011). Specific sleep stages and electroencephalographic waveforms have been shown to correlate with improvements in discrete memory domains (Mednick et al 2003, Fogel et al 2007). However, it is not known whether experimental manipulation of specific sleep features via pharmacological intervention will modulate performance. Here, in a repeated measures crossover design, we examine the effects of zolpidem (ZOL) (10mg), sodium oxybate (SO) (2.5g) and placebo (PBO) on perceptual, verbal and motor memory during a morning (9AM) nap. We tested perceptual learning with the texture discrimination task, declarative verbal memory with the word pair associates task, and motor learning with the motor sequence task before (6AM) and after (3PM) the naps. We show that ZOL decreased perceptual learning and increased verbal memory, and did not change motor learning, compared with SO or PBO. Drug effects on sleep showed that ZOL decreased rapid eye movement (REM) sleep and increased sleep spindle density, while SO increased slow wave sleep (SWS), compared to PBO. Thus, ZOL showed a trade-off between increased verbal and decreased perceptual memory, likely related a similar trade-off between spindle density and REM sleep. The magnitude of verbal memory improvement was correlated with the amount of sleep spindles in all three drug conditions, indicating that enhancements with ZOL represent an augmentation of a normal consolidation process during sleep, and are independent of drug pharmacology. These results demonstrate a causal change in perceptual and verbal memory consolidation due to pharmacological manipulation of sleep, and indicate sleep spindles as an important mechanism for memory consolidation. Furthermore, the performance gains in verbal memory exceeded those of sleep alone or with a control drug, and therefore demonstrate the capacity for "exceptional" memory enhancement with pharmacologically-specified sleep.

Acknowledgement: K01MH080992

Perceptual learning: Specificity and transfer

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

56.310 **Implicit Learning and Memory for Random Visual Noise**

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Humans are voracious recognizers of visual patterns, an ability that depends upon cooperation between perception and memory. Recent studies of auditory pattern recognition showed that after just a few encounters, observers develop and maintain an implicit memory for a particular sample of purely random noise (Agus et al., 2010). To explore the generality of those findings, we adapted Agus' approach to study the perception of random spatio-temporal visual stimuli. Specifically, we generated 1000 ms, 8 Hz samples of 1D and 2D Gaussian temporal contrast noise whose luminance levels were either uncorrelated across the entire stimulus duration ('Noise' trials) or identically repeated between the first and second 500 ms of a stimulus ('Repeat' trials). Presented with equal numbers of interleaved 'Noise' and 'Repeat' stimuli, observers judged each as a 'Repeat' or not. Additionally, half of the 'Repeat' trials comprised a fixed sample of repeated noise generated at a session's start ('Fixed repeat' noise). Similar to results from the auditory domain, d' was significantly higher for 'Fixed repeat' than 'Repeated' noise. Trial-by-trial performance with the 'Fixed repeat' noise gradually improved across a session, but the improvement was much more gradual than was seen in the auditory domain. In another experiment, the repeated half of the contrast noise sequence was presented in reverse temporal order, creating stimuli with temporal mirror image symmetry. This stimulus proved to be impossible for observers to learn, likely because of limits on working memory. Reverse correlation analyses of our main results reveal that observers placed relatively more weight upon information from a stimulus' temporal mid- and end-points. Our results show that observers can reliably develop implicit visual memories of random temporal sequences with a relatively limited amount of exposure, and that such memories are remarkably resistant to interference from multiple exposures to other temporal sequences.

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56.311 **Learning to attend transfers across spatial locations**

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Early studies of perceptual learning argued that the behavioral improvements associated with learning are largely orientation-specific, retinotopic, and monocular, and likely the result of low level sensory changes (Karni & Sagi, 1991; 1993). However, real-world instances of perceptual expertise, such as a radiologist searching for a fracture of unknown size, location, orientation, or contrast, are inherently non-specific and must transfer across low-level feature values. We have previously shown that subjects can learn a general attentional strategy when trained on nine different orientations, and that this improvement is supported by an increase in the feature-selectivity of V1 responses (Byers & Serences, VSS 2011). Because feature-based attentional modulations spread across the whole visual field (Treue and Martinez-Trujillo, 1999), we hypothesized that the benefits associated with learning to attend may generalize beyond a single spatial location. To test this, subjects learned to discriminate nine different orientations over five training sessions. Maintaining central fixation, each subject trained with a grating in one of the four quadrants on the screen and switched to a new quadrant on the sixth session. Performance improved across the training sessions and this improvement was maintained after transferring to the new location. Thus, subjects learned a generalizable attentional strategy that enhanced their ability to discriminate various orientations, irrespective of spatial location. This type of generalized learning is likely mediated by feature-selective attentional modulations that improve the precision of sensory representations of stimuli at all locations. The spatially global spread of learning in this context also provides one possible functional explanation for why feature-based attention spreads across the visual field.

Acknowledgement: RO1-MH092345

56.312 **Attention enhances perceptual learning and transfers it to untrained locations**

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Goal: Perceptual learning (PL), training-induced perceptual improvement, is usually highly specific, limited to trained locations or features. Previously, we reported that covert attention helps generalize PL to an adjacent, attended location (VSS 2009). Here we examined the effect of attention on PL at attended locations as well as unattended locations in a different quadrant of the visual field. Procedure: Participants performed an orientation discrimination task, indicating whether a briefly-presented Gabor patch of variable contrast was oriented clockwise or counterclockwise from vertical. We derived psychometric functions and calculated 75% contrast thresholds. In an initial testing session, performance was measured at four locations arranged in an imaginary square around fixation. This was followed by five training sessions, in which stimuli only appeared at two locations, placed diagonally from each other. A final testing session, identical to the first, assessed performance and improvement at all four locations. There were two groups of participants, which differed only during training sessions: For the attention group, a briefly-presented transient precue directed attention to the Gabor's location. For the neutral group, a similar cue was presented at fixation. Testing sessions were identical for the two groups and employed fixation cues. Results: During training, both groups' performance improved but improvement was greater for the attention group. Comparing the initial and final testing sessions, we found a standard PL pattern for the neutral group: performance improved at trained

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locations, but was unchanged at untrained locations. For the attention group, however, we found not only a large improvement at trained locations (threshold improvement was double that of the neutral group), but also a large improvement at the distant untrained locations (equivalent to the neutral group's improvement at trained locations). We conclude that attention enhances PL at trained locations, and also transfers it to unattended, untrained locations in a different quadrant.

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56.313 Investigating the specificity of experimentally induced expectations in motion perception

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Our perceptions are fundamentally altered by our expectations, a.k.a. "priors" about the world. In previous statistical learning experiments (Chalk et al, 2010), we investigated how such priors are formed by presenting subjects with low contrast moving dots or a blank screen, and asking them to report the direction of motion, and whether the stimulus was present. We manipulated subjects' expectations by using a bimodal distribution of motion directions such that two directions were more frequently presented than the others. We found that human observers quickly, automatically, and implicitly developed expectations for the most frequently presented directions of motion. These expectations induced attractive biases towards the perceived motion direction as well as visual hallucinations in the absence of a stimulus. Here, we examine the specificity of these expectations. Would exposure to green dots lead to particular expectations about the motion of red dots? Can one learn simultaneously to expect different motion directions for dots of different colors? We interleaved moving dot displays of two different colors, either red or green, with different motion direction distributions. When one distribution was bimodal while the other was uniform, we found that subjects learned a single bimodal prior for the two stimuli. On the contrary, when both distributions were similarly structured, we found evidence for the formation of two distinct priors, which were not strong enough to alter estimation behavior, but influenced significantly the subjects' behavior when no stimulus was present. Our results can be modeled using a Bayesian framework and discussed in terms of a suboptimality of the statistical learning process under some conditions. Understanding the limitations of statistical learning for complex stimuli may help understanding how expectations are learned at the neural level.

Acknowledgement: DTC Informatics University of Edinburgh, EPSRC, BBSRC

56.314 Right Hemifield Deficits in Judging Simultaneity: A Perceptual Learning Study

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Introduction: Right visual field (RVF) deficits have been demonstrated for several temporal vision tasks (Newman & Albino, 1977, 1979; Verleger et al., 2009; Smigasiewicz et al., 2010; Kelly & Matthews, 2011). Here, we combined signal detection theory and perceptual learning to provide new information about why and when (e.g., the visual information stage at which) RVF deficits arise in simultaneity judgments. Method: Twenty-two Denison University undergraduates judged whether peripheral Gabor targets changed orientation simultaneously versus asynchronously, and in separate blocks, whether those targets were the same or different in spatial frequency. Retinal stimulation was identical on the simultaneity and spatial frequency tasks. Trials containing RVF Gabor targets were blocked separately from LVF-Gabor-target trials. In experiment 1, we evaluated selective attention's effects by randomly interleaving trials on which Gabor distractors either appeared contralateral to the targets or were absent. In experiment 2, participants completed seven perceptual learning sessions requiring RVF simultaneity judgments on the above-described stimuli. Results: (Experiment 1) When attention was not needed to exclude distractors, signal detection theory analyses revealed a significant RVF simultaneity deficit with error patterns implicating low RVF temporal acuity, not excessive RVF neural noise. Adding attentionally demanding distractors introduced a separate, significant RVF simultaneity deficit with error patterns implicating the inappropriate integration of temporal asynchronies from distractor locations. Neither the distractor-independent RVF acuity deficit nor the distractor-induced RVF excessive spatial integration occurred for spatial frequency discrimination at the same retinal locations. (Experiment 2) Our perceptual learning procedure significantly improved RVF simultaneity judgments. The learning was task-specific but generalized to the untrained (left) visual field and to novel retinal locations. Conclusion: Our findings suggest that the RVF deficit in judging simultaneity reflects low temporal acuity and excessive spatial integration –rather than excessive neural noise– at the visual information stage responsible for the simultaneity decision.

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56.315 Perceptual learning of motion directions transfers to smooth pursuit eye movements

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GOAL Perceptual learning (PL) studies find that practice improves motion direction discrimination. We previously showed that PL affects perceived motion direction (Szpiro-Grinberg, Spering, Carrasco; ECVP 2011). However, it is unknown whether this perceptual effect would transfer to motor actions. Using a direction estimation task, we examined PL and its effect on the direction of smooth pursuit eye movements. METHOD We presented a random-dot kinematogram (75% motion coherence, drifting at 10^o/s) and after stimulus offset asked observers to estimate its motion direction by manually adjusting the angle of an arrow shown on the screen. All observers underwent a pre-test (day 1), training sessions (days 2-4) and a post-test (day5). During the testing sessions, we presented stimuli moving rightward or leftward along the horizontal axis or in a direction deviating $\pm 3^o$ from horizontal. During the training sessions, we only presented stimuli moving to one side. We conducted two experiments that differed only in the procedure of the testing sessions: in Experiment 1, observers fixated throughout the stimulus presentation; in Experiment 2, observers tracked the stimulus motion direction with their eyes. Both groups performed the estimation task. In the training sessions, all observers fixated during the stimulus presentation and then performed the estimation task. Comparing these experiments enabled us to isolate whether potential effects of PL on direction estimation would also transfer to pursuit directions. RESULTS In both experiments and for all directions PL produced an overestimation of motion direction away from the perceived horizontal. This result reveals that PL shifts perceived directions even when viewed under different retinal stimulation (fixation/pursuit). Moreover, in Experiment 2, pursuit directions also showed overestimation, as if the eyes followed the perceived directions. The results show that training perception is sufficient to alter pursuit direction, thus indicating that PL can transfer to a smooth pursuit motor response.

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56.316 Spatiotopic location specificity of perceptual learning in orientation discrimination

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Our recent study has shown that the location specificity in motion perceptual learning is not entirely retinotopic, but rather, it shows a remarkable spatiotopic component (Zhang & Li, PNAS 2010), suggesting a pliable spatiotopic processing mechanism in the dorsal visual areas representing the spatial relations of stimuli. In the present study, we investigated whether spatiotopic specificity could also exist in orientation discrimination learning that has been shown to engage the ventral visual pathway. The possible mechanisms underlying spatiotopic perceptual learning was also explored. Human subjects were trained to discriminate an orientation difference between two arrays of randomly positioned iso-oriented bars that were successively displayed at either the same or different spatial location, with their retinal locations kept unchanged by introducing a gaze shift between the two stimuli. We found that the learning was specific to the relative location of the two stimuli in spatiotopic frame of reference, and that this spatiotopic effect was seen only at the trained orientation and at the trained retinal location. This suggests plasticity in spatiotopic processing mediated by retinotopic cortex along the ventral visual pathway. Moreover, similar spatiotopic effect was also observed by randomizing the orientation of individual bars in the first stimuli, rendering it irrelevant to the orientation discrimination task over the course of training. However, when the first stimulus was hidden and thus any spatial attention triggered by the onset of the

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first stimulus was removed during training, the spatiotopic specificity was absent. These results suggest that predictive remapping of attention plays an important role in spatiotopic perceptual learning. Taken together, our observations suggest that perceptual learning can specifically modify spatiotopic visual processing, which may engage an interaction between retinotopic visual areas and higher-order spatiotopic attention mechanisms.

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56.317 **Orientation discrimination and learning may not rely on direct sensory inputs from orientation detectors**

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It is assumed that the brain relies on orientation detectors in the early visual cortex for orientation discrimination. Accordingly, perceptual learning of orientation discrimination is often interpreted as refined readout of inputs from these orientation detectors at a later decision stage. However, recent studies demonstrated that orientation learning can transfer completely across the hemispheres and to an orthogonal orientation, suggesting that orientation learning could occur in high-order brain areas. Therefore, there exists the possibility that, instead of direct readout of inputs from the orientation detectors, the high-level decision stage may rely on orientation inputs from later stages of brain processing. To test this hypothesis, we trained human observers to discriminate the explicit orientation of gratings, putatively detected by V1 neurons; or the implicit orientation of mirror-imaged dot patterns with a single axis of symmetry, unlikely detectable in V1 but most likely encoded by higher cortical areas. We compared the mutual transfer of learning between these two distinct stimuli. Learning in orientation discrimination of the symmetric dot patterns transferred completely to the gratings. In contrast, learning in orientation discrimination of the gratings transferred only partially to the dot patterns; but subsequent exposure to the same-oriented dot patterns in a suprathreshold irrelevant task (“which of the two patterns contains more dots?”) (a Training-Plus-Exposure technique, Zhang et al., J. Neuroscience, 2010) further markedly reduced orientation thresholds for the dot patterns, achieving a complete learning transfer from the gratings to the dot patterns. The complete learning transfer, especially from the implicit orientation of symmetric axis to explicit orientation of gratings, is unpredicted if orientation discrimination and its learning rely on direct readout of inputs from early orientation detectors. Our findings pose the challenge of understanding the neural computations for fine orientation discrimination and its further refinement through perceptual learning in later cortical processing.

Perceptual learning: Models

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

56.318 **Human versus Bayesian Optimal Learning of Eye Movement Strategies During Visual Search**

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There is a large literature investigating the effect of practice on the accuracy and speed of perceptual decisions. Little is known about how eye movement strategies are changed as organisms interact with perceptual stimuli and how learned oculomotor execution contributes to performance benefits. Here, we investigate changes in human eye movements given practice at a visual search task and compare them to those of a newly proposed foveated Bayesian ideal learner (FBIL) that uses posterior probabilities from previous trials as priors in subsequent trials to plan eye movements. Participants searched for a vertically aligned Gabor (8 cycles/deg) luminance signal (yes/no task with 50% probability of target presence) embedded in spatiotemporal white-noise. If present, the signal always appeared in the same location at an eccentricity of 5 degrees from initial fixation. In an “unknown” condition, observers were told the signal could be anywhere in the display, but did not know that the signal would always be in the same location. In a “known” condition, observers were told that the signal could be anywhere in the display, but it would never change locations. In each condition, trials were interleaved such that observers could either freely move their eyes or were required to hold their fixation in the center of the display. Results: Mean distance of saccade endpoints from the target location decreased across sessions in both conditions (unknown mean decrease = 4.2 ± 0.98 degrees; known = 3.0 ± 1.7 degrees) but occurred much slower than for the FBIL. Strategizing eye movements improved proportion correct (Pc) by an additional 0.23 ± .08 relative to the fixation condition paralleling the improvements by the FBIL. Together our results indicate that humans can learn to strategize eye movements to optimize perceptual performance, which can greatly contribute to performance improvement beyond learning mechanisms under steady fixation.

56.319 **A Regression Based Method for Time Series Analysis of Perceptual Learning Data**

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Typically, perceptual learning data are analyzed by segmenting the binary response sequence into blocks, calculating the discriminability d’ (or probability correct or, conversely, threshold) for each block, and fitting a nonlinear curve to the calculated d’s. This method is statistically suboptimal and introduces an unnecessary tradeoff between temporal resolution (short blocks are better) and statistical precision (long blocks are better). Worse, it ignores all learning and sequential effects within blocks. We propose a novel method that avoids these problems by leveraging the underappreciated fact that signal detection theory belongs in the class of generalized linear models (DeCarlo, 1990, Psychological Methods). We use the probit link to express the probability of responding “Right” as a function of an indicator variable S encoding the stimulus (Left=-0.5, Right=+0.5). Then the regression coefficient in front of S equals the d’ and the intercept equals (the negative of) the decision criterion. Importantly, the trial number T is included directly as a predictor and the time series is analyzed wholesale rather than in artificial segments. The learning effect is quantified by the S x T interaction. Nonlinear learning curves can be expressed with parametric (e.g., exponential) or nonparametric (e.g., spline) basis functions. Nested models can be compared by testing which predictor variables improve the fit significantly. We applied the new method to published perceptual learning data on motion direction discrimination (Petrov & Hayes, 2010, JoV; Petrov, Van Horn, & Ratcliff, 2011, PB&R). Results: 1. When the presentation sequence mixes easy and difficult stimuli, the observers apply a common decision criterion. 2. The d’ ratio between easy and difficult stimuli equals the ratio of their respective angular differences from the neutral direction. 3. The previous stimulus exerts a contrastive sequential effect. These results are consistent with the selective reweighting model of Petrov, Dosher, & Lu (2005, Psychological Review).

56.320 **Dealing with sequential dependencies in psychophysical data**

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Psychophysical experiments are the standard approach for quantifying functional abilities and properties of the visual system, and for linking observed behaviour to the perception. In most psychological experiments, human observers or animals respond to multiple trials that are presented in a sequence, and it is commonly assumed that these responses are independent of responses on previous trials, as well as of stimuli presented on previous trials. There are, however, multiple reasons to question the ubiquitous assumption of “independent and identically distributed trials”. In addition, pronounced inter-trial dependencies have been reported in mice during a visual task (Busse et al, 2011, J Neurosci). These observations raise two central questions: First, how strong are sequential dependencies in psychophysical experiments? Second, what are statistical methods that would allow us to detect these dependencies, and to deal with them appropriately? Here, we present a statistical modelling framework that allows for quantification of sequential dependencies, and for investigating their effect on psychometric functions estimated from data. In particular, we extend a commonly used model for psychometric functions by including additional regressors that model the effect of experimental history on observed responses. We apply our model to both simulated data and multiple real psychophysical data-sets of experienced human observers. We show that our model successfully detects trial by trial dependencies if they are present and allows for a statistical assessment of the significance of these dependencies. We find that, in our data-sets, the majority of human observers

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displays statistically significant history dependencies. In addition, we show how accounting for history dependencies can lead to changes in the estimated slopes of psychometric functions. As sequential dependencies are presumably stronger in inexperienced observers or behaving animals, we expect that methods like the ones presented here will become important tools for modelling psychophysical data.

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56.321 Perceptual Learning, Roving, and Synaptic Drift

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Perceptual learning improves with most basic stimuli. Interestingly, performance does not improve when stimuli of two types are randomly presented during training (roving). For example, there is no perceptual learning when left or right bisection stimuli with outer line distances of 20′ and 30′ are presented randomly interleaved from trial to trial. How can roving be explained? Perceptual learning is reward-based learning. A recent mathematical analysis showed that any reward-based learning system suffers from synaptic drift, which makes learning impossible, when two tasks are learned and the mean rewards of the tasks are not identical. Hence, we propose that perceptual learning fails in roving conditions because of the different rewards for the two roved tasks. The unsupervised bias hypothesis makes the surprising prediction that perceptual learning should also fail when an easy and a hard task are roved because of their different rewards. To test this prediction, we presented bisection stimuli with outer-line-distances of either 20′ or 30′. In both tasks, observers judged whether the central vertical line was closer to the left- or right-outer line. Task difficulty was adjusted by manipulating the center line's offset. Easy and difficult discriminations corresponded to 70 and 87 percent correct respectively. As predicted, subjects failed to learn in this roving task for both bisection-stimulus types. Hence, an easy undemanding task can block perceptual learning of another task.

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56.322 Evidence for High-Level Influences and Changes in Decision Criteria on Low-Level Visual Perceptual Learning

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Debate regarding the mechanisms underlying perceptual learning of simple visual stimuli has often been concerned with the contribution of top-down influences such as attention (e.g., Li, Piech, & Gilbert, 2004) or decision strategy (Wenger et al., 2008) on learning. For example, the extent to which (a) response properties of neurons in the primary visual cortex (Bao, Yang, Rios, He, & Engel, 2010; Kourtzi & DiCarlo, 2006), or (b), higher-order mechanisms influence learning has yet to be resolved. To investigate these issues, we carried out a complete identification experiment on six observers both before and after implementing a contrast detection threshold learning task using simple visual features. We analyzed accuracy data to examine whether the perceptual learning of visual features contributed to lower-level (a) changes in sensitivity (d′), (b) higher-level changes in decision strategy (bias, c), or both. We implemented a form of multidimensional signal detection theory known as the General Recognition Theory (Ashby & Townsend, 1986) to assess changes in perceptual (d′) and decisional separability (c) as a function of learning. We hypothesized that learning would accompany changes in perceptual separability before and after learning if learning was mainly driven by lower-level phenomena. Conversely, if high-level influences, such as decision strategy, contribute to learning, we predicted changes in decisional separability. Consistent with the latter hypothesis, we primarily observed shifts in decision criteria as a function of learning. We also obtained EEG recordings to make further inferences about the neural locus of visual learning. We observed increased deactivation in the early P1 ERP component as well as in the later P3 ERP component after learning. Evidence from the ERPs suggested changes in the response properties of neurons in the primary visual cortex (i.e., P1), and also the recruitment of higher order processes (i.e., P3).

Visual search: Attention

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Royal Palm Ballroom 6-8

56.323 Attentional Effects of Working Memory Load and Consolidation During Visual Search

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In the cued visual search paradigm, processing in working memory is known to produce a greater effect on search RT than the mere presentation of an initial cue. An item in WM which validly or invalidly cues a search target respectively decreases or increases RT. Soto and Humphreys (2008) report that increases in the task load reduce the validity effect, perhaps by reducing top-down activation from WM. It has also been suggested that effects on search occur particularly when items are being consolidated in WM. Here we examined how WM load interacts with the effect of altering the time lag between the memory cue and search displays, separating out effects from different serial positions in WM. With a 2-item WM load, the first item influenced subsequent search but this effect did not vary across the time lags. The second item had a large effect on search, the effect was independent of the WM load and it increased at the short time lag (but remained significant even with a long time lag between the memory and search displays). Decreasing effects of WM influence on search, as the WM load increases, reflect the reduced activation of early items in a WM list relative to late items. The final items in a list take time to consolidate but influence performance irrespective of the load. The results suggest that there is differential activation in WM as a function of the serial position of stimuli, that search is most strongly modulated when WM is being consolidated but that substantial WM effects remain even after consolidation has taken place.

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56.324 Parietal substrates for dimensional effects in visual search: evidence from lesion-symptom mapping

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In visual search, participants are required to detect the presence or absence of a pre-defined target. In search for pop-out targets, Müller, Heller and Ziegler (1995) found facilitated detection (i.e. faster reaction times [RTs]) when the target defining dimension remained the same compared to when it changed across trials (i.e. slower RTs). We tested the longevity of dimensional costs and benefits in search for a pop-out target in patients who have suffered from brain damage to further investigate those areas critically involved in the carry-over effects. Participants had to search for targets defined by either its color (red or blue) or orientation (right- or left-tilted) dimension. On consecutive trials, the target dimension stayed the same or changed. We categorized patients according to whether they showed an effect of dimensional change on search or not. Using voxel-based morphometry (Asburner and Friston, 2000) we compared the group of patients with dimensional effects ($N = 16$) with the group of patients without dimensional effects ($N = 9$). While controlling for spatial deficits of the patients (either to left or right; neglect plus visual extinction), whole brain voxel-wise analysis showed that damage to grey matter within the right inferior parietal lobule (the angular and supramarginal gyri and partially involving the intraparietal sulcus [IPS]) was correlated with reduced dimensional effects (cluster level corrected, $p = 0.0001$). Pollmann et al. (2006) proposed that several core anatomical structures were activated when dimensional changes occur in search, including the regions found critical in our data, and he linked the regions to the processes involved in attention shifting from one dimension to another. Our data suggest that these regions of parietal cortex are necessary to attention shifting in the context of visual dimensional change.

56.325 Investigating the neural correlates of visual attention and response selection in contextual cueing

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Response times during visual search are facilitated when target-distracter spatial configurations are repeated, a phenomenon known as contextual cueing (Chun & Jiang, 1998). According to one account, the influence of context arises from the guidance of attention to the target location in repeated contexts by long-term memory representations (Chun & Jiang, 1998), and this claim is supported by studies showing that the N2pc event-related potential (ERP) component is larger for repeated search contexts than for novel contexts (Johnson et al., 2007). According to a contrasting view, however, the effect of context is thought to be largely mediated by response selection processes (Kunar et al., 2007) rather than attentional guidance, and studies showing enhanced response-related readiness potentials (i.e., LRP) in the absence of an N2pc enhancement for repeated contexts appear to support this claim (Schankin & Schubo, 2010; Schankin et al., 2011). These conflicting results highlight that the roles of visual attention and response selection in contextual cueing remain unknown. Here we investigated the effects of repeated context on ERP components related to attention (N2pc) and response preparation (LRP). Thirteen subjects performed a visual search task in two sessions (256 trials, 50% repeated contexts) separated by one week and with 64-channel EEG recorded. Behaviorally, there was no contextual cueing effect in session 1, but there was in session 2 ($p < 0.01$). The N2pc also did not differ between repeated and novel contexts in session 1, but in session 2 an enhanced N2pc emerged for repeated displays ($p < 0.05$). Conversely, the amplitude for the response-locked LRP component did not differ between repeated and novel displays in either session 1 or session 2. These results support the notion that visual attention mechanisms, as indexed by the N2pc ERP component, play a key role in the contextual cueing effect.

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56.326 Targets Need Their Own Personal Space

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Visual search is a critical task for many life-saving professions; Lifeguards scan for struggling swimmers, airport baggage screeners search luggage for dangerous items, and radiologists examine X-rays for tumors. While these jobs often require searching very cluttered environments for multiple targets (e.g., multiple tumors in an X-ray), most laboratory research is restricted to relatively uncluttered displays with only one target. It is known that clutter can negatively influence search (e.g., Verghese & McKee, 2003), and that a second target is less likely to be detected in a multiple-target search array when a first target has already been found (e.g., Tuddenham, 1962; Berbaum et al., 2010), but do these factors interact? Little is known about interactions between target number and visual clutter, and understanding this can inform both search theory and professional searches. Here we explored visual clutter in a multiple-target search paradigm where there could be 1 or 2 targets present on a given trial, and targets appeared in varying levels of clutter. Three categories of clutter were defined based upon the number of distractor items located within a 100-pixel radius from the center of a target—no clutter (no distractors within the radius), minimal clutter (1 distractor within the radius), and high clutter (2+ distractors within the radius). There was a significant interaction between target number (1 vs. 2) and clutter (no, minimal, or high): Clutter had no effect on detecting a single target or the first target in a dual-target trial, but clutter significantly reduced detection of a second target in a dual-target trial. Multiple-target search accuracy is highly sensitive to contextual influences (e.g., Cain, Dunsmoor, LaBar, & Mitroff, 2011), and the current results reveal a specific effect wherein relatively more difficult targets (i.e., the second target in a dual-target trial) are especially influenced by visual clutter.

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56.327 When four, six, eight, or sixteen hearts beat as one: Effects of perceptual organization on search for temporal frequency outliers

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Suppose a radiologist is searching for rhythmic abnormalities in images of a beating heart. The heart is a complex spatiotemporal object. Different points move in different phases and, potentially, different frequencies. Is it easier to find an anomaly as part of a coherent structure or as one of several independently oscillating points? Observers searched for targets differing from distractors in temporal frequency. Stimuli were 4, 6, 8, or 16 dots oscillating in alternating phase. Four experiments examined a range of target frequencies, both lower (0.125 Hz, 0.25 Hz, 0.5 Hz) and higher (2.0 Hz, 4.0 Hz) than the distractor frequency (1 Hz). In the baseline, grid, condition, dots were randomly positioned on 4 x 4 grids. In the spline condition, dots connected by splines to form a single, pulsating object – a deformable circle. The radial condition omitted the splines but preserved the deformable circular configuration. Mean reaction times (RTs) depended on target-distractor similarity. RT x set size slopes declined as target frequency rose. Thus, in the grid condition, search for 0.25 Hz targets among 1 Hz distractors produced inefficient slopes >25 ms/item, while search for 4.0 Hz targets among 1 Hz distractors produced slopes in the "pop-out" range, ~0 ms/item. Critically, slopes were modulated by perceptual organization. In the spline condition, search for low frequency targets became more efficient, and search for high frequency targets became less efficient. Radial condition performance lay between the grid and spline conditions, but closer to the grid condition, suggesting that linking the dots by a single contour was more important than organizing them into a circle. As a practical matter, these results suggest that the ability to visualize relative object motion in several ways might be valuable to clinicians looking for rhythmic anomalies.

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56.328 Toddlers with ASD are better at visual search without trying harder: a pupillometric study

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Introduction: Recently, we found that 2.5-year-olds with Autism Spectrum Disorder are much better than age-matched, typically developing controls at 'feature conjunction' visual search (e.g. finding the target up to 2-3x as often in a fixed duration trial, Kaldy et al., 2011). But how does the ASD group achieve superior performance? One hypothesis is that they exert greater cognitive effort than typically developing children (searching more dedicatedly and/or faster), while another is that they search more efficiently. To examine this, we compared changes in pupil dilation (a standard measure of cognitive effort, Beatty, 1982) during search. Methods: A unique aspect of our search paradigm is that it does not require verbal instructions, making it ideal for populations with weak language skills. 17 typically developing toddlers and 17 with ASD participated (diagnosis was confirmed by ADOS, mean age: 29.6 +/- 4.8 months). Test stimuli consisted of four single-feature trials (color and shape; set sizes 5 or 9) and nine conjunction trials (set sizes 5, 9 or 13) in mixed blocks. The display was presented for 4 seconds, then the target item rotated; acting as feedback and reward. A Tobii T120 recorded eye movements and pupil diameter throughout. Results: There were no significant differences in pupil changes between the ASD and the typically developing group during search, or any of the other trial events (onset, offset, reward animation). Conclusion: Pupillometry indicates that toddlers with ASD do not exert greater cognitive effort (i.e. search harder) in conjunctive visual search than typically developing children (consistent with measures such as number of fixations and overall search time per trial, which are also not significantly different). Instead, the ASD group's superior performance is likely due to perceptual and attentional factors that raise target saliency and hence the efficiency of guided search.

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56.329 RSVPupillometry: Incidental memory and psychophysiology in rapid-serial multiple-target search.

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Often, visual search experiments involve single-target (ST) search: Observers look for one target embedded among distractors. But multiple-target (MT) search is ubiquitous; consider collecting your keys and wallet before departing from home. Importantly, MT search incurs speed and accuracy costs, relative to ST search: Observers' RTs are slowed, they make more (and longer) fixations, and they are more likely to miss and false-alarm (Hout & Goldinger, 2011a). Paradoxically, this increased workload creates more robust incidental memory for distractors encountered while viewing (Hout & Goldinger, 2010). In the current investigation, we employed a rapid-serial visual presentation task (Williams, 2010), wherein participants maintained a varying number of targets in working memory (WM) while passively viewing streams of 24 briefly presented images (centrally displayed, one at a time). This task allowed us to ensure equal encoding opportunities across conditions. Moreover, the target appeared in each quartile of the stream (early, mid-early, mid-late, late) equally often. After search, we administered a surprise, 2AFC recognition memory test for items previously seen; foils were semantically matched. Search accuracy was better under ST conditions, relative to MT, and people located the target more accurately when it appeared late in the stream, relative to earlier. With respect to incidental memory, recognition performance was better for items encountered under MT conditions, and was better for items that tended to appear after the target, relative to before it. Finally, we explored pupil diameters in order to examine attentional vigilance and its relation to subsequent memory formation (Papesh, et al., 2011). The results are discussed with respect to our preliminary model of learning in visual search (SQuEaL; Hout & Goldinger, 2011b). We suggest that MT search may involve a strategy shift, wherein cognitive resources are transferred from maintaining potential target representations in WM to the faithful encoding of incoming search items.

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56.330 Age-related effects in previewing emotional faces in visual search

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Visual search for emotional faces is influenced by the valence of the faces and/or observers' prior search experience. Here, we asked young and older adults to search for a face showing a unique emotion (emotion oddball) and to identify a second feature of the target. We investigated how previewing a display of homogeneous emotional faces affected search for the current emotion oddball, and how this inter-trial effect might change across the lifespan. For young adults, searching for a negative face among neutral faces was slower after negative faces were previewed than after neutral faces were previewed, indicating an emotional distractor previewing effect (DPE); this effect was eliminated when these faces were inverted, suggesting that the effect was not likely due to the physical features of the faces but to an evaluation of the emotional information in the displays. In contrast, older adults showed an emotional DPE in searching for negative face among neutral faces (and vice versa), regardless of whether the faces were upright or inverted. This suggests a shift in processing between young and older adults in the processing of emotional faces, with older adults performing the task based on the low level features that define emotional features, rather than on a categorization of facial emotional information as observed in young adults. The results showed that although both young and old participants are sensitive to trial history, the information that produces attentional biases across trials differs between these two populations.

56.331 Dependence of Perceptual Style on Culture

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East Asians appear to have a more holistic mode of visual memory than Westerners, being worse at recognizing objects presented in novel contexts (Chua, Boland & Nisbett, 2005), but better at recalling contextual elements of scenes (Masuda & Nisbett, 2001). There are also differences in visual search: Westerners show an asymmetry for targets defined by length (search for a long line among short is faster than short among long), whereas East Asians do not (Saiki, submitted). To investigate the origin of these effects, we tested East Asians who had immigrated to Canada. Two tasks were used. One was a memory task which examined the effect of novel context. The other was a search task: a long line among short, as well as short among long. Observers completed a questionnaire (the Vancouver Index of Acculturation, or VIA), modified to assess their affiliation to North American and their heritage culture. Search results replicated those of previous studies: no significant asymmetry in East Asians who had just arrived, but a strong one in Westerners. Immigrants who had lived in Canada for over two years also showed asymmetry, with no significant difference in degree of asymmetry between them and Westerners. Degree of asymmetry also showed some relationship with VIA score. Interestingly, when long-time immigrants were tested using their native language, search asymmetry disappeared. Meanwhile, the degree of context-dependence on the memory task did not depend on length of time in Canada. These results indicate that cultural factors can affect perceptual style; these may reflect differences in visual environment. They also indicate that adapting to new cultures can result in new perceptual styles, even in adults. However, the old style remains available for use.

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Attention: Features II

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

56.401 Does practice make perfect: an examination of performance during the Emotional Stroop paradigm

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We are examining whether practice during our newly designed emotional stroop paradigm (Ovaysikia, Tahir, Chan and DeSouza, 2011 Frontiers in Human Neuroscience) can change behaviour in two related measures (1) performance as measured with reaction times and error rates and (2) during practice do people change their eye movement patterns to the stimuli. The current study evaluated the relationship between the emotional Stroop task practice and emotional Stroop task performance. This variation of the emotional Stroop task employed photos of happy, neutral and sad facial expressions arranged in composite face-word images, with emotional words (either happy, neutral or sad) being superimposed on but not obscuring facial expressions. Four participants, mean age of 22.5 years (SD = 2.4) all had either attained English language fluency by age 12. Emotional Stroop stimuli were presented on a 19-in., 60Hz monitor, a viewing distance of 50 cm, the visual angles were as follows: fixation cross 1.22°; images 17.14° (vertically) and 12.07° (horizontally). Consistent with our previous study, we found the emotional Stroop task variant produced interference effects similar to the original Stroop (1935) task. Of greater relevance to the effect of practice, the findings of the current study provide strong evidence that emotional Stroop practice significantly shortens reaction time (RT) in emotional Stroop performance compared to baseline. In addition, eye traces analysis revealed practice predicted a modification in gaze or fixation localization, during the "after" condition showing a significant shift or reallocation of a portion of fixations further down the stimulus closer to the proximity of the mouth when compared to the "before" condition. These data suggest emotional Stroop practice has the potential to improve decision making RT involving conflicting stimuli, and that the performance improvement may be partially mediated by a modification in oculomotor strategy.

Acknowledgement: NSERC

56.402 "Please tap the shape, anywhere you like": The psychological reality of shape skeletons

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An intriguing hypothesis in research on shape perception is that shapes are represented in terms of their inferred interior structure, rather than their visible borders. Such 'skeletal' or 'medial axis' shape representations are thought to afford computational efficiency and flexibility. However, an old (and in our view tragically unheralded) report from the 1970s supported the psychological reality of such representations, using a remarkably direct method: subjects were presented with a 2D shape drawn on paper, and they simply used a pencil to make a single dot within the shape. When many subjects' dots were aggregated, the resulting plots bore a striking resemblance to a traditional shape skeleton. Here we revive this paradigm for the digital era, replicating previous effects and extending them in several new ways. Using a tablet computer with a touch-sensitive screen, hundreds of observers were shown geometric shapes (including some that changed size and shape dynamically during viewing) and were simply asked to "touch the screen, inside the shape, anywhere you like". We discovered just when the aggregated touches did and did not reveal shape skeletons — including tests of several types of stimuli that to our knowledge have not been considered in the shape-representation literature. We also employed this method to test predictions made by specific computational accounts. For example, one prominent account based on Bayesian estimation holds that subtle perturbations in a border should not affect the computed shape skeleton. The psychological effects of such perturbations, however, were quantitatively large and visually striking: whereas the aggregated touches in a normal rectangle lined up with the conventional medial axis transformation, the addition of even a very small notch near one corner dramatically altered this pattern. We discuss these and many other results in (re)introducing this surprisingly direct window onto otherwise-hidden visual processes.

56.403 **Object-Based Attention is Impervious to Nearby Targets During Visual Search**

Adam Greenberg[1], Maya Rosen[1], Kayla Zamora[1], Elizabeth Cutrone[1], Marlene Behrmann[1]; [1]Department of Psychology, Carnegie Mellon University

Recent studies on the representational basis of attention have suggested that uncertainty of either the target location (Shomstein & Yantis, 2002, 2004) or the target-defining feature (Greenberg, 2009) promotes object-based selection, whereas target certainty promotes space-based selection. Here, we examined the effects of visual search strategy on the magnitude of object-based attention. Displays contained a single rectangular object among gray (parallel search condition) or multicolored (serial search condition) distracters, which appeared 300 ms after an exogenous cue at one end of the rectangle. Subjects searched for a green target (or orange, for half the subjects) positioned at one of four locations relative to the cue: (1) valid location on the object, (2) invalid location, far end of the object, (3) an equidistant invalid location not on the object, or (4) random background location. In Experiment 1, search slopes for background targets were positive when distracters were multicolored and flat when distracters were gray, confirming that subjects employed serial and parallel search, respectively. Robust same object advantage values were observed during both search strategies, presumably because the target location was uncertain in both conditions. However, serial search produced a significantly larger same object advantage than parallel search, suggesting that object-based selection may be modulated by the seriality of the transmission of selected information. We ran two additional experiments during which the invalid, off-object target was moved closer to the object by a distance of ~1/2 (Expt. 2) or ~3/4 (Expt. 3), creating a spatial advantage for this location compared to the invalid, on-object target. Unexpectedly, neither of these manipulations produced a significant reversal of the same object advantage. This suggests that proximal locations not on the selected object are prioritized lower than distal locations on the object. Object-based selection, therefore, is surprisingly resistant to distraction during conditions of target spatial uncertainty.

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56.404 **Subitizing is resource-limited and not preattentive**

Bjorn Hubert-Wallander[1](bjornhw@uw.edu), Jeffrey Y. Lin[1], Sung Jun Joo[1], Scott O. Murray[1], Geoffrey M. Boynton[1]; [1]Department of Psychology, University of Washington

Classic research tells us there are two distinct systems that allow us to count the number of items in a visual display. When the number of items is large, counting is slow, effortful, and prone to error. But when the number of items is small (usually less than 5), a supposedly preattentive process called subitizing appears to operate, quickly and accurately apprehending the number of items present. Recently, however, the preattentive nature of subitizing has come into question. Here, we used a dual-task version of the classic subitizing task in order determine if subitizing is a resource-limited process. Participants were asked to accurately count the number of items in two arrays presented in quick succession. We hypothesized that if counting small numbers of items relies on preattentive or parallel processes, then the number of items in the first array should have no effect on counting performance in the second array, as long as either or both arrays were in the traditionally-defined subitizing range. Instead, we observed a continuous linear decline in accuracy for counting in the second array as a function of number of items in the first array, even when the number of items in the first array was small. Furthermore, the effect of the first array was clearly present even when the analysis was restricted to small set sizes in the second array. Interestingly, a follow-up experiment demonstrated that when subjects were not required to count the number of items in the first array, the first array had no effect on accuracy for the second array, ruling out perceptual factors and suggesting that the resource that limits subitizing performance may indeed be attention. Our results demonstrate that subitizing both affects and is affected by the amount of cognitive resources available to the viewer and may not be preattentive.

56.405 **Multiple target individuation with and without distracters**

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Previous studies have shown that the visual system can select simultaneously up to approximately 4 elements in the visual field. However, little evidence exists on how such simultaneous selection takes place when both relevant and irrelevant multiple objects are presented, namely when specific objects have to be distinguished not only from each other but also from other irrelevant ones. Using Event-Related Potential (ERP) recordings this study sought to get new insight into multiple target individuation by combining traditional enumeration paradigms (in which multiple targets are presented in isolation) with typical visual search tasks (in which at least one target is presented among distracters). Participants saw a variable number (from 1 to 4) of lateralized target elements presented with or without distracters in the target side, and performed an enumeration task. Results showed that while an early non-lateralized response (N1, 120-180 ms) is modulated by target numerosity only without distracters in the target side, the amplitudes of a lateralized and later response (N2pc, 180-300 ms) increased as a function of target numerosities in both conditions (reaching a plateau at 3 targets). We propose that the stage reflected in the N1 may correspond to the initial indexing of items on the basis of their spatial properties alone. This stage is sensitive to the overall amount of elements presented in the visual field, rather than to the quantities of a specific subset of (target) elements. In contrast, the N2pc may reflect the component of individuation that binds only relevant properties and locations, as inferred by its lateralized nature and by its target numerosity-related modulations both with and without distracters. As a result of this operation, a coarse representation of the relevant objects becomes available, allowing the visual system to individuate them in the visual field and making them ready for further processing.

56.406 **Decoding location and category information in human parietal cortex**

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To understand the neural mechanisms mediating the selection and encoding of multiple visual objects, previous findings showed that the human inferior intra-parietal sulcus (IPS) selects and individuates objects based on location and the superior IPS encodes the feature information from the selected objects. However, it is unclear whether inferior IPS also encode object feature information and whether superior IPS always encode object features regardless of the task demand. To answer these questions, using multivariate pattern analysis, we examined fMRI response patterns for object category and location encoding in inferior and superior IPS. In the first experiment, observers were shown blocks of images from one of four object categories in one of two locations and detected occasional vertical or horizontal movement of the stimuli. We found that inferior IPS response was predominately location based, consistent with its overall role in location-based processing. Interestingly, inferior IPS also showed a small but significant category selectivity. Superior IPS, on the other hand, showed neither location nor category selectivity. To investigate whether the lack of category selectivity in superior IPS was task specific since the motion detection task did not engage any category specific processing, in the second experiment, we asked observers to perform a 1-back object identity repetition detection task. Preliminary results showed that, with this task, superior IPS exhibited significant category selectivity. Taken together, these results indicate that inferior IPS contains strong location selectivity and weak category selectivity even when the encoding of such information was not necessary, supporting its role in automatic visual object individuation. Superior IPS, in contrast, seems to only encode object category information when it is task relevant, suggesting the flexibility of information representation in this brain region.

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56.407 **V1 saliency theory makes quantitative, zero parameter, prediction of reaction times in visual search of feature singletons**

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Tuesday PM

The V1 saliency theory (Li 1999, 2002) hypothesizes that the saliency of a visual location is determined by the maximum activity across V1 neurons responding to that location. It has provided qualitative predictions, various of which have been confirmed experimentally. Here, we show that, without using any free parameter, it makes quantitative predictions of the probability distributions of reaction times (RT) for searching for feature singletons. For example, a red vertical bar activates some V1 neurons tuned to red color, some V1 neurons tuned to vertical orientation, and still other V1 neurons tuned simultaneously to red color and vertical orientation. According to the theory, the saliency at its location is determined by the highest response across these three types of neurons. Consequently, when every visual input item can take only one of the two possible feature values along any feature dimension, the RT for finding a feature singleton unique in both color and orientation is statistically shorter than the RT for finding either a singleton unique in only color or orientation. V1 has no neuron tuned simultaneously to the three feature dimensions: color; orientation; and motion direction. Thus, we can derive from the V1 saliency hypothesis a mathematical relationship between the probability distributions of seven RTs. Three of the seven RTs are for finding singletons having a unique feature in only one of the three feature dimensions; three more are for finding singletons having a unique feature in two of the three feature dimensions (e.g., unique in both color and orientation); and finally one RT is to find a singleton having a unique feature in all three feature dimensions. One can thus predict quantitatively the distribution of one of the seven RTs from those of the other six. This prediction will be compared with behavioral data (Koene and Zhaoping 2007).

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56.408 **Individual differences in object-based selection are predicted by visual short-term memory capacity**

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People can selectively maintain task-relevant features of items in visual working memory (Woodman & Vogel, 2008), but can they effectively ignore task-irrelevant features of an attended item? And, if so, does the ability to ignore irrelevant feature dimensions correlate with visual short-term memory (VSTM) capacity? Participants performed a priming of popout task with six oriented color gratings arranged in a circle around a fixation point. They tried to locate the one grating that differed in orientation (vertical or horizontal) from the other gratings. Across consecutive trials, there were four possible types of target repetitions: only orientation, only color, both orientation and color, or neither orientation nor color. Importantly, the color of the oddball grating (red or cyan) was irrelevant to the orientation detection task. Overall, subjects responded faster to the oddball target when its orientation, color, or both dimensions repeated compared to when neither dimension repeated; that is, both the relevant and irrelevant dimension of the target produced priming. The size of the priming effect when both dimensions repeated was negatively correlated with VSTM capacity, suggesting that people with low VSTM capacity were more influenced by the irrelevant color of the target. Contrary to the idea that attending to an object automatically leads to processing of irrelevant dimensions as well, we find that individuals vary in the extent to which they process irrelevant dimensions and that this variation is predicted by VSTM capacity.

56.409 **Attention and feature misbinding in visual working memory**

Mia Y. Dong[1,2](mia.y.dong@gmail.com), Nahid Zokaei[1,2], Masud Husain[1,2]; [1]Institute of Cognitive Neuroscience, UCL, [2]Institute of Neurology, UCL

Working memory (WM) and attention are intimately connected, but the precise relationship between the two processes is unclear. Here we investigated whether attention load during maintenance had an effect on precision of WM recall. In separate experiments, participants viewed a memory array of either random dot motion kinematograms or oriented bars, of different colours. Following a blank interval, a visual search task with varying levels of difficulty (attention load) was presented. Participants were asked to respond as fast and as accurately as possible. After a further delay, they were probed on their memory: adjusting a coloured probe to match either the motion direction or the orientation of the bar with the same colour in the memory array. In both experiment, participants were slower and made more errors on the visual search task under high compared to low load, confirming that attention load was successfully manipulated. Precision of WM recall was significantly lower in high compared to low load and baseline (no visual search) conditions. Furthermore, the proportion of responses around the target decreased under high load compared to the other two conditions. Crucially, this was accompanied by an increase in the proportion of responses around non-target features (i.e., directions or orientations of other items in the memory array that were not probed), demonstrating feature misbinding in WM. A probabilistic model of performance used to examine possible sources of error in WM also revealed that the loss in precision under high load was purely explained by an increase in non-target responses. Thus, under high attention load, features of other items in the array contaminated recall of the direction of motion or orientation of the probed item. These findings suggest the resources used for attention (visual search) are also employed for maintenance of feature binding in WM representations.

56.410 **Object state-change predicts neural similarity of visual representations before and after a described event**

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Recent eye-tracking, self-paced reading, and neuroimaging studies suggest that tracking multiple representations of the same object as it undergoes a state-change engenders conflict due to having to distinguish the 'before' and 'after' states of the object (Altmann and Kamide, 2009; Hindy et al., under review). We use fMRI and multi-voxel pattern analysis to test the degree to which an object state-change causes a distinct neural representation of the same object. We varied whether an object was minimally changed by a described action (e.g., "weigh the pumpkin") or substantially changed by the action (e.g., "carve the pumpkin"), and measured the neural similarity between imagined visual representations of that object before and after the action. Each experiment trial began with a briefly presented object photograph, followed by a sequence of three visual imagery task instructions separated by fixation: imagine the object, then imagine a specified action that involves the object, and finally imagine the object in its final state after the action. Subsequent to the three visual imagery segments, a retrieval cue instructed participants to indicate which of two clipart images is most similar to the object at either the beginning or end of the trial. In object-selective regions of ventral temporal and lateral occipital cortex, we find that the multi-voxel pattern similarity across time points before and after the described action was significantly reduced when the object was substantially changed, compared to when the object was minimally changed. Furthermore, this neural similarity between the 'before' and 'after' brain states varied parametrically with the rated degree to which the object was changed in state by the described action. Results suggest that, when representing object state-change, a distinct representation of the same object is instantiated in the ventral visual processing pathway, even though the distinct representation is not the result of visual processing.

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56.411 **Counting multidimensional objects – implications for the neural synchrony theory**

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It has been suggested that a neural instantiation of the temporary multidimensional representations of objects might be the synchrony of firing between the neurons representing the features they contain. In this work, we direct attention to a certain logical problem which arises when certain synchrony assumptions are applied to real situations in which repeated multidimensional objects are presented. Then we demonstrate a new behavioral effect that shows that this logical problem results in a genuine behavioral problem. Even when a display contains a small amount of multidimensional objects, their representation becomes difficult when according to our described assumptions the objects cannot be simultaneously synchronized.

56.412 **Ensemble-based Subitizing**

Robert Eisinger[1](reising1@jhu.edu), Ryan Ly[1], Hee Yeon Im[1], Justin Halberda[1]; [1]Johns Hopkins University

The enumeration of a small number of objects has been repeatedly shown to consist of two distinct stages dependent on the number of objects. For 1-3 objects, enumeration is fast and accurate. For more than 3 objects, enumeration is slow and less accurate. The former is coined subitizing and the later is counting. These results have led many authors to suggest that each object is selected as a single unit by visual selection or preattentive visual indexing mechanisms (eg. FINSTs) and that subitizing elbows arise because adults are limited to selecting 3 or 4 individual object units at any time. In separate literature, research has been interested in showing ensemble statistics (eg. average size) may empower the visual system to work around the restrictive object based limits. Here, we use subitizing as an assay to test the possibility that an ensemble group of many items must first be selected as a single coherent unit (eg. one group) prior to processing ensemble features for this group. In several experiments, we find that adults show a subitizing elbow when asked to enumerate the number of spatially separated ensembles in a scene. And, just as object based subitizing is disrupted when objects are organized concentrically (Pylyshyn, 1994), ensemble based subitizing is disrupted under these same conditions.

56.414 **Interactions between space-, surface-, and object-based attention**

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It has been previously demonstrated that attention can be allocated to regions of space or perceptual objects. Although they are not mutually exclusive, the exact relationship between the two modes of selection is not fully understood yet. Egly, Driver, and Rafal (1994) first showed both components within one paradigm, but cuing a location inside an object confounded the space/object reference frames. The present study dissociated space and object using two variants of the Egly paradigm. Experiments 1 and 2 were Go/No-Go tasks in which the spatial and object validity was either high or low (80% vs. 20%) and the target appeared at a cued or uncued location inside a cued or uncued object (CLCO, ULCO, CLUO, ULUO). The two objects formed a cross-like display with one occluding the other in Experiment 1, and a ring-like display with two banana-like shapes in Experiment 2. In particular, the design of these stimulus configurations enabled a new condition (CLUO) in which a part of one object could occupy the same spatial location as a previously cued object. We found both space- and object-based effects within these paradigms when object validity was high. More importantly, spatial and object validity interacted – the object-based effect was smaller when the spatial location was cued. In contrast, when attention was allocated to a specific location under high spatial validity, only a space-based component of visual attention was observed. With spatial cuing, a location-based representation appeared to suffice and attention did not spread readily through the whole object. Together, the results are suggestive of selection at different levels of processing and raise questions about the role of perceptual surfaces in object-based attention.

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56.415 **Uncertainty Reduction: The guiding principle of object-based selection**

Sarah Shomstein[1](shom@gwu.edu); [1]George Washington University

Research to date has shown that under some circumstances attentional selection is guided by object representations (Chen & Cave, 2006, 2008; Goldsmith & Yeari, 2003; Martinez et al., 2006; Richard, Lee, & Vecera, 2008; Shomstein & Behrmann, 2006, 2008; Shomstein & Yantis, 2002, 2004). However, the full understanding of why under some circumstances such guidance is possible has remained elusive, partially due to a lack of a theoretical framework with corresponding clear predictions, and partially due to a somewhat dogmatic approach to testing alternative theories. Given a critical mass of knowledge acquired on the topic, the need for a unifying framework is imperative. Here, we propose such framework termed the uncertainty reduction hypothesis, proposing that when uncertainty in the input is high (e.g., the location of the target or the target identity is unknown) the visual system integrates most of the available information embedded in the environment to guide attentional selection, thus yielding object-based effects. If, on the other hand, uncertainty is low, then resources are most efficiently allocated almost exclusively to the relevant information, thus reducing object-based effects. Evidence from a set of behavioral and fMRI experiments, utilizing different paradigms, will be reported in which uncertainty is manipulated with various external (sensory) and internal (reward) factors. Results from four experiments consistently show that as uncertainty in the input increases (e.g., location or color of the upcoming target is unknown), so do the magnitudes of the observed object-based effects. Additionally, our findings show that internal factors, such as reward, serve to reduce uncertainty, thereby minimizing object-based effects. We propose that the uncertainty reduction hypothesis has the potential to unify a large body of evidence on the topic of object-based guidance, opening new avenues for investigations elucidating the mechanisms of attentional selection.

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56.416 **Effects of Metacontrast and Object-Substitution Masking on Subliminal Priming**

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Responding to the direction of a target stimulus (“less than” or “greater than” signs) is facilitated by a congruent priming stimulus, if that prime is fully visible. However, if the prime is masked by a pattern consisting of features of both target stimuli, responses are actually slower following a congruent prime than following an incongruent prime—the “negative compatibility effect”. Two theoretical explanations have been offered: (1) Partial activation, below the threshold of conscious awareness, is followed by self-inhibition (Eimer & Schlaghecken, 1998); (2) Priming is dominated by the “new” mask features rather than the “old” features shared with the prime (Lleras & Enns, 2004). Experiments in which the mask features were varied have yielded inconsistent results, possibly because dissimilarity between prime and mask features increases the likelihood of awareness of the prime. We attempted to address the issue by using different masking paradigms—metacontrast and object-substitution—in which masking depends less on featural similarity between mask and prime. In the metacontrast procedure, the prime was followed by a surrounding annulus at varying stimulus-onset asynchronies. In the object-substitution procedure, four flanking dots remained in view for 100 ms after the offset of the prime. We were unable to obtain a negative compatibility effect in either procedure. A particularly surprising result in the object-substitution procedure was a greater positive priming effect when the prime was masked than when it was not masked. This effect may be due to the task-relevance of the dot-mask in locating the target. Nonetheless, the result implies a paradoxical dissociation between attention-enhanced priming and conscious awareness of the prime.

Face perception: Neural mechanisms

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

56.419 **Frequency-tagging EEG stimulation reveals integration of facial parts into a unified perceptual representation**

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The human face is the perfect example of a Gestalt, a visual stimulus for which the whole is more than the sum of the parts. While there is ample evidence for interactivity of processing among facial parts - the processing of a given part of a face being influenced by the identity and position of the other facial parts - direct evidence for the integration of face parts into a unified representation is still lacking. Here we investigated this issue by means of the frequency tagging stimulation technique (Regan & Heron, 1969) applied to facial parts. High density (128 channels) scalp electroencephalogram (EEG) was recorded in 15 participants presented with a composite face whose top and bottom parts’ were contrast-modulated at different frequency rates (5.87 and 7.14 Hz, counterbalanced). The same composite face was presented throughout 70 sec sequences while participants had to detect colour changes on a fixation cross below the eyes. Responses at several harmonic frequencies were recorded over the visual cortex. Most importantly, intermodulation components (F1+F2= 13.01 Hz; F1-F2: 1.26 Hz), reflecting the interaction of the two input frequencies were observed. While the response to fundamental frequencies remained unchanged or even increased following inversion and spatial misalignment of face parts, the amplitude of the IM components largely decreased in these conditions. A second study (15 participants) controlling for border effects between the aligned and misaligned conditions rendered the same results, that is, a strong and specific decrease of the IMs after misalignment and inversion of

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the face stimulus. Altogether, these observations provide the first objective trace of a unified face representation in the human brain and of its disruption by spatial misalignment of facial halves and inversion of the whole stimulus, two common manipulations used in the field of face processing to disrupt holistic face perception.

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56.420 Adaptation of the steady-state visual potential response to face identity: generalization and temporal dynamics

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The amplitude of the Steady State Visual Evoked Potential (SSVEP) response at a specific stimulation frequency is larger over right occipito-temporal cortex when different faces are presented compared to when identical faces are presented (Rossion & Boremanse, 2011, JOV). Such SSVEP sensibility to variations in facial identity is observed for stimulation frequencies between 3Hz and 10Hz and is maximum at about 6Hz (Alonso-Prieto,., and Rossion, JOV, 2011 vol. 11, 643). Currently, it is not known whether this effect is modulated by the presence of internal and external facial features, e.g. skin color and hair. This issue is relevant for the validity of the SSVEP approach in face perception research because the appearance of the facial stimuli, which is frequently manipulated in face perception studies, can influence the SSVEPs. Six observers were confronted with a sequence of faces (15s of identical faces followed by 69s of either identical or different faces) presented at 4.00Hz (or faces/second, one cycle = 250 ms) and 5.88Hz (one cycle = 170 ms) while high-density EEG (128 channels) was recorded. Four types of faces were presented: 3D laser-scans pictures, full color pictures with external features, color and grayscale photographs with cropped external features. The SSVEP response at the stimulation frequency was larger for different than identical faces for all stimulus types. At 5.88Hz, the strongest response was obtained for different full-color faces with external features. Time-course analysis of EEG data showed that the response at the stimulation frequency increased until about 10s and then decreased when the same face identity was presented. It immediately reincreased when different faces were introduced (16th second). These observations indicate a fast, large and stimulation frequency-specific release to face identity adaptation in the human brain and corroborate the reliability of the SSVEP approach to study face perception processes.

56.421 Temporal frequency tuning of the cortical face-sensitive network for individual face perception

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The human brain is particularly efficient in face discrimination, a function that appears to be supported by a set of cortical areas sensitive to individual face adaptation. However, the rate at which individual faces can be discriminated remains unknown. Here we investigated the temporal frequency tuning of face-sensitive areas with functional magnetic resonance imaging (fMRI). Four observes were tested (5runs each) with an adaptation paradigm where blocks of same or different faces were presented at 11 different frequencies (1, 2, 3, 4, 5, 6, 6.66, 7.5, 8.57, 10, 12 Hz; same face identity or different identities at each cycle). In most pre-localized face-sensitive area and in particular in the right middle fusiform gyrus (FFA) we observed that, on average, the adaptation effect - computed as the difference between same and different faces - was peaked at 6 Hz. The analysis of the same and different conditions (separately) revealed that such an effect was due to both the quick drop of the signal during the transition from 4 to 6 Hz in the same condition and to a larger response for different faces (different condition) which decreased for frequencies higher than 6 Hz. The present study suggests that individual face discrimination is optimal when a face is presented around a rate of 6Hz. Interestingly, at this rate, the complete cycle of the sinusoidal stimulation of a face lasts about 166 ms which is also the latency of the earliest face identity adaptation effect as found on the face-sensitive N170 ERP component after flash stimulation (Jacques et al., J Vis, 2007). Therefore, while the exact nature of the relation between the N170 and the phenomenon reported here is still to be determined, our results support the view that the human brain requires about 160 ms to process individual facial information efficiently.

56.422 Evidence from the EEG frequency tagging stimulation technique for a unified representation of faces independently of the amount of border between top and bottom halves

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Numerous behavioral studies have shown that when the top and bottom halves of a face are spatially misaligned, the processing of the top half is no longer influenced by the identity of the bottom half. At the last VSS meeting, we showed that this effect is disrupted by a very small spatial misalignment between the two face halves (e.g., 8% of face width, Laguesse & Rossion, 2011). However, direct evidence for the integration of face parts into a unified representation when the two halves of a face are aligned vs. misaligned is still lacking. To address this issue, we used the frequency-tagging stimulation technique (Regan & Heron, 1969) derived from the steady state Visual Evoked Potential (SSVEP). Eight participants were presented with faces composed of top/bottom parts flickering at different frequencies (at 5.88 or 7.14 Hz, counterbalanced across different stimulation blocks of 40 sec). The parts could either be aligned, or spatially misaligned with a shift of 0.34, 0.69, 1.03 or 1.37 degrees of visual angle (5 conditions). The contiguous border between the top/bottom halves was kept constant across conditions by increasing the size of the whole stimulus with misalignment. Electroencephalogram (EEG) was recorded (128 channels) and transformed to the frequency domain (FFT). For the fundamental frequencies of stimulation, frequency-specific increases were found in the medial occipital region for all conditions. Most importantly, over the right occipito-temporal channels, EEG increases were found at several intermodulation terms (e.g., 5.88 + 7.14 = 13.02 Hz) for the aligned condition only. This study provides strong evidence for facial parts integration in the right occipito-temporal region that is independent of the amount of border between the two parts. These results are consistent with our previous behavioral study showing the disappearance of the composite face effect/illusion when parts of the face are slightly misaligned.

56.423 Investigating face identity matching and discrimination using event-related steady-state visual evoked potentials

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Humans are very efficient at discriminating and matching highly similar visual patterns such as faces. Yet, the perceptual mechanisms underlying this ability remain unclear. Following the recent application of the steady-state visual evoked potential (SSVEP) method to study individual face perception in a block design (Rossion & Boremanse, 2011, JOV), we extended this method to investigate the encoding of facial identities in an event-related stimulation mode. We recorded high-density EEG (128 channels) in 7 human observers presented with a 60-second sequence of face stimuli shown at a constant, high frequency rate (12.5 Hz, sinusoidal contrast modulation). At fixed intervals (every 4 stimuli, or 12.5 Hz /5 = 2.5 Hz) we introduced either a change (Experiment 1, discrimination) or a repetition (Experiment 2, matching) of facial identity. More precisely, in Experiment 1 (AAAABAAAAC…), different identities (B, C…) appeared at 2.5 Hz, the amplitude at this frequency being taken as an index of identity discrimination. Conversely, in Experiment 2 (ABCDDEFGHH…), the 2.5 Hz repetition of the previous identity is considered to reflect identity matching. Low-level visual differences were controlled by face orientation (upright vs. inverted) and by randomly varying face size at each cycle of the main 12.5 Hz frequency. In both experiments, we found an increase of EEG amplitude and signal-to-noise ratio at 2.5 Hz and its harmonics (2F=5 Hz, 3F=7.5 Hz, 4F=10 Hz), which was localised predominantly over right occipito-temporal electrodes. Importantly, responses were much larger for upright than inverted faces in this area. These findings suggest not only that facial identity could be extracted despite the fast presentation frequency but also that the encoding was of a holistic rather than analytical nature. This demonstration prompts further investigation of face perception with this event-related approach in different human populations, including children and individuals with difficulties in face recognition.

56.424 Decoding EEG data reveals dynamic spatiotemporal patterns in perceptual processing

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We investigated the efficacy of multivariate pattern analysis (MVPA) for revealing EEG correlates of visual perception. EEG was recorded with 64 scalp electrodes from four participants as they passively viewed grayscale stimuli varying along four dimensions: location (left or right visual field), category (face or Gabor), subcategory (male or female faces; high or low spatial frequency Gabors), and orientation (upright or inverted faces; horizontal or vertical Gabors). Group-averaged ERPs showed typical temporal shifts and amplitude differences for both contralateral-versus-ipsilateral stimuli and upright-versus-inverted faces. Using linear support vector machines, we performed MVPA on the same EEG data with approximately 1-ms precision to see if stimulus differences could be classified on a trial-by-trial basis. EEG signals occurring at specific time points (174 ms and 674 ms for left-versus-right classification, 180 ms and 271 ms for face-versus-Gabor classification, and 219 ms for upright-versus-inverted face classification) reliably predicted perceptual differences with accuracy ranging from 67% to 93%. Importantly, the critical time points were virtually identical for the four subjects. Although corresponding group-averaged ERPs differentiated a subset of these conditions, MVPA predicted stimuli on an individual subject level, provided remarkably consistent estimates of the timing of perceptually relevant neural information on a trial-by-trial basis, and revealed additional time windows of discrimination accuracy. MVPA did not reliably classify horizontal vs. vertical Gabors, low vs. high spatial frequency Gabors, or female vs. male faces, suggesting that the highly reliable trial-by-trial predictions described above are not an artifact of our MVPA method. Thus, MVPA of trial-by-trial EEG data is a robust complementary approach to ERPs as it uncovers unique neural correlates of visual processing.

56.425 Factors affecting inter-hemispheric transfer of categorical visual information

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Stimuli presented in one visual hemifield are usually transferred from the contralateral to the ipsilateral hemisphere. However, it is not evident that such transfer always occurs and, if it does, what is the kind of information that is transferred. Presenting faces and chairs randomly in the right or in the left visual hemifield while healthy participants monitored the screen for occasionally appearing flowers elicited a robust bilateral N170-effect (N170 elicited by faces was larger than that elicited by watches), regardless where the stimuli were presented. The latency of the N170 was faster by about 10 ms in the hemisphere contralateral to the stimulus location. When the N170 elicited by two faces presented simultaneously one in the left and one in the right visual field was compared with that elicited by two simultaneously presented chairs, the bilateral N170 effect occurred at the same latency in each hemisphere. However, when a face and a chair were simultaneously presented one in the left and the other in the right visual field, comparing such composite stimuli with stimuli composed of two chairs yielded an N170-effect only in the hemisphere contralateral to the location of the face. In the hemisphere contralateral to the chair an N1 emerged, which did not distinguish the chair-face pair from the chair-chair pair. This pattern suggests that when each hemisphere receives different information and the task requires only a shallow categorization, there is no transfer of categorical information from one hemisphere to another. It is assumed that when the task involves a deeper level of analysis (such as person identification) the hemispheres should cooperate and categorical information should be transferred from one hemisphere to another even with competing bilateral stimulation. If so, a bilateral N170 effect should be observed even when a face-chair stimuli are compared with chair-chair stimuli

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56.426 The brain basis of emotional aftereffects: An ERP study

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Aftereffects have been demonstrated for various types of visual stimuli including faces and emotional facial expressions. Aftereffects are assumed to be mediated by neural adaptations, but brain responses during the perception of facial expressions aftereffects have not been measured. In the current study we measure event related potential (ERP) brain responses in an emotion aftereffect paradigm with happy and sad faces. Participants were 22 undergraduate students (13 females) (Mean age = 19.6 years; SD = 1.98). First, we replicated previous behavioural results of emotion aftereffects: after fixating a happy face, a neutral face was more likely to be labelled sad, and vice versa. We also found that ERP amplitude was predicted by the strength of the aftereffect, when the percept was happy. Interestingly this was not found with neutral faces perceived as sad, which may indicate different processing mechanisms for positive and negative facial expressions. The fact that the brain response in viewers who perceive the neutral face as happy resembles that of the brain response to a happy image, rather than a neutral image, suggests a brain basis for facial aftereffects.

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56.427 Parametric face-to-hand transformations reveal shape-tuned representations in human high-level visual cortex.

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Previous fMRI studies (e.g., Weiner & Grill-Spector, 2010; 2011) document alternating and adjacent face- and limb-selective regions throughout human ventral temporal and lateral occipitotemporal cortices (Figure 1a), but the functional properties of these regions remain poorly understood. Because localizer images typically differ in many low-level, textural and global properties, it is unclear what aspects of face or limb images drive responses in these regions. Further, it is unknown whether responses in adjacent face- and limb-selective patches are driven by stimulus properties or by the perceived category of the stimulus (or whether the relative contribution of these factors differs across regions). Building on the face silhouette methodology (Davidenko, 2007; Davidenko, Remus, & Grill-Spector, 2011), we generated a novel set of parameterized silhouette stimuli that span a continuous morph space between faces and hands, while their low-level properties are well controlled (Figure 1b). We defined stimuli at 5 morph levels, ranging from fully face-like (level-1) to fully hand-like (level-5), and behaviorally calibrated intermediate (level-3) stimuli to appear equally face-like and hand-like. In an fMRI block-design experiment, we measured the mean BOLD response in face- and limb-selective regions as participants observed these stimuli. We found that responses in face-selective regions in the middle (mFus-faces) and posterior (pFus-faces) fusiform gyrus and inferior occipital gyrus (IOG-faces) decrease monotonically as stimuli become less face-like and more hand-like. In contrast, responses in nearby limb-selective regions in the occipital temporal sulcus (OTS-limbs), inferior temporal gyrus (ITG-limbs), lateral occipital gyrus (LOG-limbs) and medial temporal gyrus (MTG-limbs) increase monotonically as stimuli become more hand-like. Our results demonstrate that these face- and limb-selective regions are tuned to stimulus shape and their responses can be parametrically modulated by morphing stimuli away from a preferred category.

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56.428 Anatomy, Retinotopy, & Category Selectivity in Human Ventral Visual Cortex

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We examined the relationship between anatomy, category selectivity, and retinotopy in ventral visual cortex of 13 subjects using fMRI. Each subject participated in 3 experiments: 1) a functional localizer identifying face- and place-selective regions, 2) phase-encoded retinotopy to define retinotopic maps, & 3) an experiment where faces or houses were presented either foveally or peripherally to examine the relationship between category selectivity and eccentricity preference (Levy 2001). First, we replicate previous findings regarding the organization of ventral visual cortex including: 1) multiple face patches: IOG, mFus, pFus, and aFus (Weiner, 2010,Tsao 2008, Rajimehr, 2009), 2) hV4/VO organization (Brewer 2005), 3) overlap of parahippocampal (PHC) visual field maps with the PPA (Arcaro 2009), and 4) alignment of eccentricity preferences with category selectivity (Levy

2001). Second, we integrated these findings with anatomical constraints into a single organization extending that of Weiner 2010 by including: 1) Posterior posterior transverse collateral sulcus (COS) to guide the location of hV4/VO and face-selective IOG, 2) anterior transverse COS to distinguish between mFus and aFus, 3) posterior extent of the hippocampus as landmark for the anterior extent of retinotopy, a boundary between mFus and aFus patches, and marking where place selectivity spreads from the COS onto the PHC, and 4) alignment of face patches with distinct retinotopic clusters (hV4, VO, PHC).Third, we examined the eccentricity preferences of face and place regions finding 1) increased position tolerance from posterior to anterior with different preferences across IOG, pFus, mFus and aFus face patches and position invariance in place-selective regions appearing only anterior to visual field maps, and 2) different pattern of eccentricity bias for face and place-selective regions. The results bear directly on systematically defining commonly used functional regions (FFA, PPA), and suggest a hierarchical axis of visual processing from posterior to anterior in ventral cortex.

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56.429 Effect of context on the N170 for low spatial frequency filtered faces

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People typically rely on middle spatial frequencies (SF) for face recognition, and stimuli containing only low SFs can be difficult, or even impossible, to recognize (Gold et al., 1999). One explanation for this effect is that the horizontal information around the eyes/eyebrows that people rely on most for face recognition (Dakin & Watt, 2009; Sekuler et al., 2004) may not be the most informative for discrimination for low SF faces. Here we ask whether the processing of low SF filtered faces can be influenced by altering the context in which they are presented, or whether the stimulus drives processing strategy through bottom-up information. We measured N170s for low SF filtered faces presented in a 10AFC identification task. Participants were randomly assigned to one of two context conditions: face or texture. In the face condition, trials intermixed unfiltered faces with low SF filtered faces. In the texture condition, trials intermixed textures with low SF filtered faces. In both conditions, observers completed 200 trials of each stimulus types, for a total of 400 trials. Observers' behavioural performance was similar for unfiltered faces and textures, and, as expected, unfiltered faces led to large N170s, while textures did not. For low SF filtered faces, performance was significantly reduced compared to that of both unfiltered faces and textures, but it did not vary significantly across conditions. In contrast, the EEG results for low SF filtered faces varied considerably across conditions: participants in the face condition showed strong N170, whereas those in the texture condition showed no significant N170 even though the stimuli were identical in the two conditions. Hence, the N170, but not response accuracy, was sensitive to stimulus context. These results suggest that subjects used different processes in the two conditions, even though performance was the same.

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56.430 Decoding orientation-invariant information about individual faces in the ventral stream

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In order to recognize individual faces we need to distinguish very similar images (specificity) while also generalizing identity information across image transformations such as changes in luminance and rotations in depth (invariance). The neural mechanisms that underlie the ability of preserving identity information across image transformations remain unclear. We investigated the presence of orientation-invariant information about faces applying information-based mapping to the BOLD signal in the ventral stream, training a pattern classifier to discriminate different faces seen from 4 orientations in depth, and testing its performance at discriminating those faces seen from a fifth novel orientation. Rather than showing a gradual increase from the posterior to the anterior ventral stream in the presence of informative voxels for orientation-invariant classification, we find that informative voxels cluster at the level of the fusiform and at the level of the anterior temporal lobes. To investigate the presence of orientation-invariant information in standard regions of interest, we defined ROIs for the OFA, FFA and right ATL using an independent localizer. Highly localized orientation-invariant information about faces was detected in the right ATL, where patterns of activity extracted from a small number of voxels allowed to achieve cross-viewpoint face classification significantly above chance. Orientation-invariant classification of faces was also achieved in FFA and OFA when considering larger numbers of voxels, while classification in V1 remained at chance. These results suggest that representations in the FFA and OFA encode visual details about the faces, while representations in the right ATL seem to abstract away from such details and can therefore be contained in a smaller extent of cortex.

56.431 Translation tolerant and category-selective encoding of orientation in the fusiform face area

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The fusiform face area (FFA) is a region of the human ventral visual pathway that exhibits a stronger response to faces than objects. The precise role of this region for face perception is not well understood, and its face selectivity has been debated. Furthermore, it is unclear which properties of visual stimuli are systematically reflected in the patterns of activation of this region. Prior research suggests that FFA might encode face orientation. Here we directly explore the encoding of orientation using a combination of functional magnetic resonance imaging (fMRI), multivoxel pattern analysis (MVPA) and computational modeling. We presented subjects with synthetic images of faces and cars that were rotated in depth and displayed either above or below fixation. We then explored orientation-related information available in fine-grained activity patterns in FFA, lateral occipital (LO) and early visual cortex (EVC). Distributed signals from FFA allowed above-chance classification of orientation within category only for faces. This finding generalized to faces presented in different retinotopic positions. In contrast, classification in EVC and LO resulted in comparable, above-chance classification of face and car orientation information, but only when trained and tested on corresponding retinotopic positions. Classification accuracies across position were substantially decreased for both categories in LO, while not different from chance in EVC. Finally, we compared a computational model of population coding in FFA with the data using representational dissimilarity analysis. We conclude that: (i) category-selective effects of stimulus orientation are reflected in the fine grained patterns of activation in FFA, (ii) the structure of these patterns is tolerant to translation, (iii) frontal views of faces are most robustly represented, and (iv) our decoding results presumably reflect an inhomogeneous distribution over voxels of spatially clustered angle-tuned neural populations.

56.432 A pattern classification approach to discriminating neural responses to faces and bodies in motion

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The specialized neural functions associated with the visual processing of faces and bodies span multiple cortical regions in ventral temporal (VT) and superior temporal (ST) cortex. We used pattern classification to separate the neural activity elicited in response to viewing moving and static presentations of faces and bodies. Using fMRI, participants (n = 8) viewed 12-second blocks of videos of people walking toward a camera and 12-second sequences of the "best" static images from the videos. For dynamic and static presentation types, participants saw: 1.) videos/images of the whole person (WP); 2.) videos/images of the body with the face pixilated (B); and 3.) videos/images of the face with the body obscured (F). Pattern classifiers were implemented to discriminate all pairs of conditions (e.g., dynamic F vs. dynamic B) in each participant's brain. Neural activation patterns were highly discriminable for static-to-static (Mean d' = 2.22, se = .21) and motion-to-motion (Mean d' = 2.15, se =.24) comparisons (F vs. B, F vs. WP, B vs. WP) in functionally localized face/object selective regions of VT cortex. For both cases, F vs. B and F vs. WP activations were more separable than B vs. WP. In ST cortex, these conditions were separable also, but with the motion-to-motion F vs. B comparison significantly more discriminable than the other comparisons. For motion vs. static conditions, neural activity

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maps in the VT cortex were separable only for cross-condition comparisons that included the face (F vs. B, F vs. WP; Mean d' = 1.58, se = .35). Within a condition (e.g., moving F vs. static F), the neural activation maps could not be separated at levels above chance (Mean d' = -0.23, se =.48). This study offers a systematic dissection of the neural representations of human face and body motion in a natural stimulus.

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56.433 The neural correlates of illusory face perception: An fMRI study

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Individuals often report seeing a face in the clouds, their toast, or a tortilla. These informal observations suggest that our visual system is highly tuned to perceive faces, potentially due to the high social importance of faces or face processing expertise. Previous fMRI studies of this top-down bias to perceive faces have mainly examined the neural correlates of imagining faces or perception of ambiguous faces. However, the neural mechanisms underlying the illusory processing of faces are unclear. To address this question, in the present study, participants were instructed to detect faces (face task) and letter (letter task) in pure noise images after training in which increasingly noisy face or letter images were used. The pure noise images actually contained neither faces nor letters. Trials were classified into 4 conditions according to whether participants responded that they had "seen" a face or a letter in a pure noise image: face response, no-face response, letter response, and no-letter response. A repeated two-way ANOVA of task (face vs. letter) by detection (face or letter response vs. no response) was performed on the fMRI activities of each face-preferential area, namely the fusiform face area (FFA) and the occipital face area (OFA). Results revealed that the right FFA showed significantly greater activity for face responses than for no-face responses, whereas it showed equal responses to the letter and no-letter response. Within the left FFA and bilateral OFA, regardless of the face or letter task, the neural activity for detection responses was significantly greater than no-detection responses. Our findings suggest that the right FFA is specifically involved in the illusory processing of faces, whereas the left FFA and the bilateral OFA are involved in the illusory processing of visual objects more generally.

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56.434 Face-voice integration in person recognition

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Audiovisual integration (AVI) is known to be an important mechanism in speech perception, but evidence for AVI in person recognition has been less clear. We demonstrate AVI in the recognition of familiar (but not unfamiliar) speakers. Specifically, systematic behavioural benefits in recognising a familiar voice occur when it is combined with an articulating face of corresponding speaker identity, whereas costs occur for voices combined with precisely time-synchronised noncorresponding faces. In a series of behavioural experiments, we show that AVI in person recognition (a) depends on familiarity with a speaker, (b) is sensitive to temporal synchronization of facial and vocal articulations (with a qualitatively similar, but quantitatively extended integration time window, when compared to AVI in speech perception), and (c) occurs both for voice and face recognition tasks. Subsequent experiments with event-related brain potentials (ERPs) compared unimodal (face only, voice only) conditions with audiovisual conditions (AV corresponding, AV noncorresponding). The results suggest that audiovisual speaker identity correspondence influences later ERPs beyond 250 ms only, with increased right frontotemporal negativity for noncorresponding identities. In two separate experiments, the above findings were demonstrated both for face-voice combinations using sentence-stimuli as well as McGurk-type syllable utterances. Remarkably, when compared with the summed responses from both unimodal conditions, both audiovisual conditions elicited a much earlier onset of frontocentral negativity, with maximal differences around 50-80 ms. Overall, electrophysiological data demonstrate AVI at multiple levels of neuronal processing. Although the perception of a voice and a time-synchronised articulating face triggers surprisingly early and mandatory mechanisms of audiovisual processing, audiovisual speaker identity may only be computed about 200 ms later.

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56.435 Not All High-Level Aftereffects are Equal (And Perhaps None is Opponent Coded)

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After prolonged exposure to a female face, faces that had previously seemed androgynous are more likely to be judged as male. Research into such high-level categorical aftereffects has predominantly focussed on human faces, but more recent research suggests that such effects are generic, impacting judgments involving multiple object classes. High-level categorical aftereffects are thought to be caused by adaptation within a norm-based opponent code, akin to low-level analyses of colour. While a good deal of evidence is consistent with this, some recent data is contradictory, motivating a more rigorous test. In behaviourally matched tasks we compared the characteristics of aftereffects generated by adapting to colour, to expanded or contracted faces, to facial gender, and to different species of animal. In our experiments opponent coding predicted that the appearance of the adapting image should change and that adaptation should induce symmetrical categorical boundary shifts. This combination of predictions was firmly supported for colour adaptation, but not for any other condition. Interestingly the two face aftereffects tested were caused by distinctly different patterns of response shift relative to colour adaptation, and relative to each other. Our data suggest that high-level categorical aftereffects are not caused by adaptation within an opponent code. Instead, superficially similar aftereffects seem to ensue from several different combinations of visual adaptation within a population coding scheme, contrast effects, and/or changes in decision-making criteria.

56.436 The "informational correlates" of consciousness

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What distinguishes conscious from non-conscious visual perception? We investigated this question from an information-processing perspective by exploring which spatial frequencies (SFs) are correlated with observers' responses during conscious vs. non-conscious face perception. Specifically, we used a face-gender repetition priming paradigm and the SF Bubbles technique (Willenbockel et al., 2010) to precisely map the SFs that prime as a function of awareness. A "visible prime" condition was set up by presenting the stimulus sequence mask-blank-prime-blank-mask-target (prime, blank, and mask durations ≤ 50 ms); an "invisible prime" condition was created by reversing the order of the masks and the blanks (see also Dehaene et al., 2001). Twenty grayscale face photographs (10 males; visual angle ~3º) served as primes and as targets, whereby the prime faces were randomly SF filtered trial-by-trial. Results show facilitatory priming effects in response times for both visibility conditions, albeit smaller for the invisible prime condition. A multiple linear regression on the SF filters from each trial and the transformed response times revealed that fast responses were linked to specific SFs (~12 cycles per face width) in the visible prime condition, but not to any specific SFs in the invisible prime condition. Interestingly, the SFs that led to faster responses in the visible prime condition led to slower responses in the invisible prime condition. The results imply that different visual information primes as a function of awareness and therefore provide strong support for a qualitative conscious/non-conscious dichotomy.

56.437 Emotional Saliency Allows for Unconscious Face Adaptation

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Whether adaptation aftereffects occur for high-level stimuli features without conscious perception remains controversial. For example, adaptation aftereffects for unconscious stimuli features have been found for facial emotional expressions but not for face gender, race, or identity. Here, we tested two hypotheses that can account for the discrepancy in the results. The first hypothesis proposes that the null results of adaptation aftereffects on identity-related features is due to some unaccounted motion aftereffects or forward masking by the image used to suppress images from conscious-

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ness. To test this hypothesis, we rendered faces with strong gender characteristics unconscious with continuous flash suppression (CFS) on one half of the hemifield. Then, we briefly presented a face with neutral gender identity on the other unsuppressed hemifield and asked subjects to classify the gender of the face. We observed a gender adaptation aftereffect in trials without CFS. That is, the neutral face was more likely to be classified as male when observers were presented with a face with strong female features beforehand and vice versa. This effect, however, is absent in trials with CFS. The results suggest that the absence of an adaptation aftereffect is not due to unaccounted effects of the mask used for CFS. The second hypothesis proposes that emotionally salient stimuli are a special case of stimuli that can be processed to an advanced stage without conscious perception. We replicated the experimental procedure for the first experiment, but we made the faces with strong gender features emotionally salient by using faces with fearful facial expressions. Note that the observers were still classifying the gender of the neutral gender face presented afterwards. We find that a face gender aftereffect for trials without and with CFS. This suggests that emotional information is processed unconsciously in a manner that can support identity processing of a face.

56.438 The neural correlates of own- and other-race face recognition and categorization: A fMRI study

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Faces from one's own race and those from other race are processed in different ways. The most direct evidence supporting such hypothesis comes from two paradoxical cross-race effects. One is the own-race recognition advantage that refers to a more rapid and accurate individual recognition for the own-race faces than that for other-race faces. Another is the other-race categorization advantage, whereby when categorizing face by race, individuals categorize other-race faces fast and sometimes more accurately than own-race faces. However, no neural imaging study has concurrently examined the neural correlates underlying these two cross-race effects. Here, we used a 2 face race (Caucasian vs. Chinese) × 2 task (individual recognition vs. race categorization) within-subject factorial design to bridge this gap. We compared the activation between own-race faces and other-race faces as well as between the individual recognition task and the race categorization task. Results revealed a significant interaction effect of face race by task type within the fusiform face gyrus (FFA) as well as the occipital face area (OFA). Further, in each of them, the own-race faces elicited equal responses to the two tasks, whereas the other-race faces produced greater responses in the individual recognition task than in the race categorization task. Our findings suggest the response of the FFA and OFA to own-race faces is insensitive to the change of task demands, whereas their responses to other-race faces can be enhanced, perhaps by shifting from a default categorical level to the individual level of processing. Given the significant roles of the FFA and OFA play in the identification of individual faces, our finding is consistent with the hypothesis that the own-race faces can be by default individually recognized regardless the task demands, whereas the other-race face can be automatically classified by race unless an instruction of recognition is explicit.

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56.439 Selectivity for Mirror-Symmetric Views of Faces in the Ventral and Dorsal Streams of the Human Visual System

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Although the ability to recognize faces and objects from a variety of viewing angles is crucial to our everyday behavior, the underlying cortical mechanisms are not well understood. Recently, specific neurons in the macaque inferior temporal lobe were found to be selective for mirror-symmetric views of faces rotated in depth, and not responsive to intermediate views (Freiwald & Tsao, 2010). This property has been suggested to constitute a key computational step in achieving full view-invariance. Using fMRI and multivariate pattern analysis (MVPA), we investigated whether such selectivity for mirror symmetry might also be found in human visual cortex. We measured BOLD activity in nine observers, as they viewed upright or inverted faces presented at five different angles (-60, -30, 0, 30, 60 degrees). To estimate the effects of viewpoint symmetry, we tested whether the activation patterns for mirror-symmetric views (e.g., -60 and 60 degrees) were more similar than those involving non-symmetric views (e.g., -60 and 0 degrees). Two analyses were performed, one on predefined ROIs and one based on a searchlight technique. We found that viewpoint-symmetric response patterns are prevalent in the human visual system. Importantly, these mirror-symmetric activity patterns were not confined to a single face-selective area. Instead, the effect was present in a large band of higher-order visual areas, including the occipital face area, posterior and anterior segments of the fusiform face area, as well as the lateral occipital complex, parahippocampal place area, and extending superiorly to encompass dorsal regions in the posterior intraparietal sulcus. Critically, early retinotopic regions V1-hV4 did not show these effects. Our findings suggest that the selectivity for mirror-symmetric viewpoints may constitute a general intermediate-level processing step shared across multiple higher-order areas of the visual system, setting the stage for complete viewpoint-invariant visual representations in more anterior areas of the visual hierarchy.

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56.440 The role of the uncinate fasciculus in human visual-associative learning

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The uncinate fasciculus (UF) is a cortico-cortico pathway that links the temporal and frontal lobes. In non-human primates transection of the UF causes impairment in learning visuo-visuo and visuo-motor associations, while object discrimination remains intact. Here, we used diffusion tensor imaging (DTI) and behavioral experiments to examine the role of the UF in mediating visual associative learning in humans. Specifically, we sought to establish whether there was any correlation between learning performance and the structural properties of the UF in 18 participants who were trained to learn associations between specific sets of indoor and outdoor visual scenes and individuals (six female, caucasian faces, oriented in three possible viewpoints). In each trial, a scene was presented along with two faces (Target/Distractor) and participants were asked to match the scene to the target individual. Visual and auditory feedback was provided after each trial. In total, participants learned 36 associations over 1080 trials. To measure the structural and architectural properties of the UF, we collected diffusion-weighted images (120 directions). After correcting the DTI data for artifacts, the data were split into two halves of 60 directions each. For each half of the data a tensor volume was reconstructed and standard DTI measures were computed. From one tensor volume, streamlines depicting the bilateral uncinate fasciculi (UF), and inferior longitudinal fasciculi (ILF) were extracted using deterministic tractography. The streamlines from each pathway were used as a mask to compute the mean fractional anisotropy (FA) and mean diffusivity (MD) within the tract from the independent tensor volume. Correlation analyses between the learning rate in the behavioral task and tract measures revealed a strong relationship between learning and structural properties of the UF, but not other tracts. These findings highlight a role for the human UF in visual associative learning similar to that reported in monkey.

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3D perception: Cue combination

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

56.444 **Size, shading and disparity: studying cue combination using visual search**

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Studies investigating cue-combinations between binocular disparity and shading tend to adopt either forced-choice or method-of-adjustment paradigms. The results of such studies are constrained by the limitations and demand characteristics of each approach. For example, forced-choice paradigms do not allow perceptual biases to be explored; method of adjustment approaches use probes which require prolonged response times, and such probes are problematic for exploring single-cue use. Visual search was used to explore depth perception from shading, size and binocular disparity. We presented naive observers with a shaded rectangular box, lit from above, containing a circular array of grey discs. For each disc we manipulate the disparity, size and shade independently, as if each cue were drawn from a disc at a different depth. Observers were asked to press a single response button as quickly as possible once they had decided which disc was the 'deepest' item in the scene. The scene was then removed and masked. They were then asked to indicate the location of the deepest disc. We modelled disc selection using a variety of models that weighted and combined the individual cues to depth. Observer selections were not reliably predicted by maximum-likelihood estimates (MLE) of cue combinations (based upon JNDs derived from separate discrimination trials). Rather, deepest disc selections were biased towards disparity cues, even when other discs might be deeper on shade and size axes. Mean performance for MLE model predictions of disc selections were 51% (up to 58%) correct (chance levels were 10-25% depending upon the number of discs in a stimulus). Alternative models, where cue weightings were divergent from channel reliability, achieved 67% correct on average. We conclude that disparity, shading and size cues are not combined as a function of their recent perceptual reliability or discriminability.

Acknowledgement: EPSRC UK, (EP/G038708/1)

56.445 **Perceptual integration of specular highlight and shading**

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In natural scenes, shading and specular highlight often coexist under the same lighting condition. Previous studies have suggested independent mechanisms for these cues in the perception of 3D structure. Circular patterns with the same polarity of gradation pop out from those with the opposite polarity in an array of the patterns (Ramachandran, 1988). When the gradation is replaced by specular highlight (without shading) , the pop-out vanishes, suggesting fundamentally distinct mechanisms for shading and highlight. We investigated psychophysically the integration of specular highlight and shading in the perception of 3D structure. Specifically, we examined whether and how specular highlight facilitates the perception of 3D structure from shading, and analyzed the mechanism for the integration of the two cues. We performed psychophysical experiments in a visual search paradigm using the circular arrays with the expectation of pop-out based on shading. To control shading and highlight, we integrated a variety of real/realistic specular highlights into artificial shading. A single circular pattern including a gradation (target) was embedded into an array of circular patterns including the opposite polarity of gradation (distractors). The participants were asked to answer when one found the target. The results showed that combinations of highlight and shading reduce significantly the reaction time. This reduction holds even when specular highlight is inconsistent with shading, indicating that highlight and shading work in a facilitative fashion but not in suppressive. Furthermore, the analysis of the reaction time indicated that specular highlight facilitates multiplicatively the perception of 3D structure, and that the facilitation depends on the characteristics of specular highlight including the direction of light source. These results support that the cortical mechanisms for shading and specular highlights in 3D perception are independent, and that they are integrated in a highly nonlinear fashion.

Acknowledgement: Grant-in-aid from MEXT of Japan (KAKENHI 22300090 & Shitukan 23135503)

56.446 **The integration of disparity and shading cues to 3D shape in dorsal visual cortex**

Dicle N. Dovencioglu[1](dnd842@bham.ac.uk), Hiroshi Ban[1], Andrew J. Schofield[1], Andrew E. Welchman[1]; [1]School of Psychology, University of Birmingham, UK

The brain integrates a range of depth cues to estimate depth. Psychophysical results show this improves discrimination; e.g., judgments are more precise when disparity specifies depth in combination with cues such as texture, motion and shading. Here, we test for the cortical circuits involved in representing depth structure from integrated cues. We presented participants (n=15) with random dot stereograms in which convex ('bump') and concave ('crater') surfaces were depicted using (i) binocular disparity, (ii) Blinn-Phong shading and (iii) disparity and shading in combination. Further, we included a control condition in which convexities and concavities were specified by binocular disparity, and dots in the upper and lower portions of the stimuli were given different luminance levels (binary shading). This ensured differences in the spatial distribution of luminance in the stimuli, but did not contribute to the impression of depth structure. We measured psychophysical judgments of these shapes, finding evidence of enhanced depth estimates when disparity and shading simultaneously signalled depth. We then measured fMRI responses to these stimuli, using a blocked design and measuring responses in independently-localized regions of interest. We analysed our data by measuring the prediction performance of a support vector machine trained to discriminate surface shape (convex vs. concave). In cortical area V3B/KO we find that prediction performance improves significantly when depth structure is concurrently specified by disparity and shading, and this improvement exceeds the minimum bound expected for integration (quadratic summation prediction from component cue accuracies). Moreover, this result is specific to combined cue stimuli, with binary shaded stimuli supporting prediction performance comparable to that of disparity-defined surfaces. Our results are consistent with recent work showing the integration of disparity and motion in area V3B/KO and suggest that this area is a crucial cortical locus integrating depth cues in the human brain.

56.447 **The integration of texture- and disparity-defined slant in the human brain**

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The visual system exploits multiple depth cues to achieve an accurate interpretation of the 3D environment. Psychophysical studies demonstrate that the integration of texture and disparity signals is near optimal, reducing variance when estimating surface slant. However, the cortical circuits responsible remain largely unknown. Here we test for cortical responses that relate to the integration of texture and disparity cues to slant. We measured human psychophysical judgments and fMRI responses to stimuli containing texture and disparity-defined slants. Participants viewed planes in which disparity and texture cues were independently manipulated to indicate one of two angles of slant (+60°/-30° rotation about the horizontal axis). Stimuli contained either 'single' cues ('texture only' and 'disparity only'- in which case the other cue signalled 0° slant), or combined cues ('congruent texture and disparity' or 'incongruent texture and disparity'). Psychophysical tests revealed that observers were more sensitive to slant discrimination for congruent combined cue stimuli compared to individual cues, the quadratic summation of individual cues or incongruent cues. The fMRI data were analysed by training a support vector machine (SVM) classifier to predict the slant angle (+60°/-30°) of stimuli based on patterns of activation in functionally localized regions of visual cortex. SVM classification accuracies for stimuli containing congruent texture and disparity cues exceeded those predicted by quadratic summation of single cue accuracies (i.e. the minimum bound for integration) in higher regions of both ventral and dorsal cortex (LO, V3B/KO and V7). This improvement was specific to congruent combinations of cues: incongruent cues supported lower decoding accuracies, which may suggest the robust use of individual cues in cases of large cue conflicts. These results are consistent with recent evidence that indicates that disparity and motion parallax depth cues are integrated in area V3B/KO, suggesting this area is intricately involved in the integration of multiple depth cues.

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Acknowledgement: Wellcome Trust

56.448 The role of binocular disparity and projected size in the detection of curved trajectories

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The current study examined the roles of binocular disparity and projected size in the detection of curved trajectories. Subjects were shown computer-generated displays of a sphere that traveled in the horizontal plane from a simulated starting position 8.6cm to the left and 122.1cm away from the observer to an ending position 8.5cm to the right of and 105.0cm away from the observer. On each trial observers were shown two displays. In one display the motion of the sphere was along a straight trajectory at a constant 3D speed; in the other the motion was along a constant curved trajectory at a constant 3D speed. To produce binocular disparity, all displays included reference objects presented 209.6cm away from the observer. A two-alternative forced choice procedure was used without feedback and observers were asked to indicate which display simulated a curved trajectory. Three independent variables were manipulated: viewing condition (binocular vs. monocular), type of curve (concave vs. convex relative to the observer), and projected size (constant 3D or constant 2D). The eight conditions were run in separate blocks counterbalanced across sessions. We found that, relative to monocular viewing, binocular viewing resulted in greater detection performance for convex curved trajectories. There was no significant difference between monocular and binocular viewing for concave curvatures. In addition, no systematic effects of projected size were observed. These results indicate that binocular information is more important than size information in detecting convex-curved trajectories. In addition, the importance of disparity information for convex trajectories suggests that change in disparity at the start of the motion path (which was greater for convex as compared to concave trajectories) is important for detecting curved trajectories.

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56.449 Persistence of Monocular Depth Perception in the Low Resolution Limit

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Purpose Monocular depth cues can provide a vivid sense of depth through image structure (such as perspective and occlusion) or through differential changes with movement (such as motion parallax). Nevertheless, it is unclear how the perception of depth from these cues degrades with resolution, and in particular how it degrades with block pixellation at low resolution. Depth perception with block pixellation in the low resolution limit is of considerable interest, as it has application to retinal prostheses that are implanted within only one eye. Furthermore, in the case of block pixellation, the high spatial frequency noise of pixellation edges masks low-frequency monocular depth cues, generating the perception of a flat image. Pixellation also generates false depth cues, such as same-size objects (pixels) bordered by parallel lines (pixel edges), thereby indicating a single image depth. Post-pixellation blur removes the false depth cues and unmasks the real depth cues to generate a vivid sense of depth. Results Nine naïve subjects rated the depth they perceived in natural images at varying levels of pixellation and blur. Depth ratings of block pixellated images were compared with images of the same resolution that had been block pixellated and Gaussian blurred. Further study showed that even after recognition of an image feature, a significant difference between the depth ratings of pixellated images and those of pixellated and blurred images persisted. Dynamic depth cues such as motion parallax were also studied with motion video, demonstrating similar striking differences. Conclusions Depth perception caused by monocular depth perception cues was found to be impaired when the images were pixellated. The impairment was found to be alleviated with the addition of optimal post-pixellation Gaussian blur. Optimization of monocular depth perception in the low-resolution limit may critically improve the functionality of low-resolution visual prosthetic devices (such as intraocular retinal prostheses).

Acknowledgement: National Science Foundation, National Science Foundation Graduate Research Fellowship

56.450 Familiarity Dominates Shape-From-Motion Signals in the Concave-to-Convex 3D illusion

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OBJECTIVE: Investigate role of top-down influences on recovering 3D shape from motion information, using objects varying in familiarity to test familiarity's role on the tendency to perceive concave surfaces as convex. BACKGROUND: We reported (Papathomas et al, VSS 2011) that rotating hollow masks are perceived as convex faces rotating in the opposite direction, even in conditions where shape-from-motion signals have previously generated concave 3D percepts for artificial stimuli. We now test directly whether these results were dominated by object familiarity. METHODS: Experiment 1 used hollow, realistically painted, physical stimuli rotating on a turntable: (1) facial mask, (2) watermelon. Experiment 2 used four computer-generated concave stimuli: (1) Realistic human mask, using FaceGenTM; (2) ellipsoid rendered as watermelon; (3) ellipsoid with random-dot texture; (4) ellipsoid shown by longitude and latitude gridlines. In both experiments, the center (C) of the turntable was at a fixed distance from the observer. For artificial stimuli, motion parallax signals dominate the percept (Zaidi et al, 2011). We manipulated parallax by using 6 different rotational radii (distance between C and stimulus centroid). The illusion-strength was estimated by the time reported in the illusion divided by the total time that the concave side faced the observer. RESULTS: Experiment 1: The illusion was obtained for significantly longer intervals for the face than the watermelon; illusion-strength did not vary significantly with rotational radius. Experiment 2: Illusion-strength, averaged across rotational radii, was significantly higher for the human mask (44%) and watermelon (47%) than for the random-textured (35%) or gridline (28%) ellipsoids. CONCLUSIONS: The experiments provide evidence for a top-down bias to perceive familiar objects as convex that is greater than the bias for less familiar objects. Real objects are predominantly convex, so familiarity significantly influences the recovery of 3D structure and shape from bottom-up data-driven motion signals.

Acknowledgement: EY013312 and EY07556 to Q.Z.

3D perception: Neural mechanisms and models

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Orchid Ballroom

56.453 Navigating in a changing world: enhancing the discrimination between view-based and Cartesian models.

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View-based and Cartesian representations provide rival accounts of visual navigation in humans. We previously (VSS 2011) developed Cartesian and view-based models to explain human performance on a simple homing task in an immersive virtual reality environment. Here we show how the discriminability of the two models can be enhanced by introducing subtle (unnoticed) changes in the scene between the reference and 'homing' intervals. In interval one, participants were shown three very long coloured vertical poles from one viewing location with some head movement permitted so that both binocular stereopsis and motion parallax over a baseline of up to 80cm provide information about the 3D layout and position of the poles relative to the participant's location. The poles were easily distinguishable from one another, and designed to have constant angular width irrespective of viewing distance. The participant was then transported (virtually) to another location in the scene and, in interval two, they attempted to navigate to the initial viewing point relative to the poles. Critically, the location of one of the poles was changed slightly between intervals one and two, where the exact shift was chosen so that rival models could be distinguished most readily. Specifically, our models predicted distributions that

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differed from one another not only in shape, but also in the actual mean point to which people were expected to walk in the virtual room. In the case of view-based models, the shifting pole also allows us to discard many candidate models from the large set we have proposed previously. Overall, the view-based models continue to provide a better description of the human data on this new dataset, with likelihoods averaging four times those of the 3D-based models.

Acknowledgement: Wellcome Trust

56.454 How do we point at an unseen object?

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One of the key arguments against view-based methods as a model of navigation and spatial representation is that such models cannot (at present) explain the following performance: an observer (human, animal or robot) views two objects in one visual direction, one of which is closer to the observer than the other; the target objects disappear while other objects in the scene remain; the observer translates to a new location and then orients in turn towards the original targets (which remain invisible). Accurate performance on this task requires information (in some form, not necessarily metric) about the distance of the targets at the initial location. It is often assumed to require, in addition, a metric representation of the scene. Here we show through simulation that view-based information alone is adequate to carry out this task with reasonable accuracy over a range of conditions without the need to generate a metric reconstruction of the scene. We collect information about the change in relative visual directions (RVDs) of pairs of points in a 'flatland' 2D scene caused by a short-baseline translation (binocular stereo or motion parallax) collected at two locations (A and B) separated by a wide baseline. Using these RVDs and changes in RVDs, we show how it is possible to orient towards a subset of points that cannot be seen from a third location (C). In simple cases, such as C lying on the line AB, this is relatively straight-forward to achieve. We show, over a range of locations of C, the extent to which RVDs and changes in RVDs (optic flow and stereopsis) around A and B can support accurate pointing to unseen targets without the use of a metric map.

Acknowledgement: Microsoft Research, Wellcome Trust

56.455 The Generic Linear Motion Assumption for the interpretation of the optic flow

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3D surface structure is not fully specified by the Optic Flow (OF) produced by the relative motion between an observer and a planar surface. Current theories postulate that the visual system interprets the OF by combining retinal measurements of image velocities with extra-retinal information about the observer's egomotion. By introducing some assumptions in the interpretation process, veridical estimates of Euclidean 3D structure can, in principle, be derived from the OF. However, recent empirical findings hinder the biological plausibility of such approach by showing that perceived 3D structure is not veridical and that egomotion signals are seldom used in the perceptual interpretation of the OF. Here, we present a new model for perceived 3D structure from the OF that (1) disregards the linear motion of the observer's Point of View (PoV), (2) relies on the assumption that the OF is produced by a generic linear motion of the PoV, (3) derives the most likely 3D structure by integrating over the missing motion parameters. A tenet of our approach, which we term the Generic Linear Ego Motion (GLEM) assumption, is that the translational components of the OF are diagnostic of egomotion. This model makes counterintuitive predictions that cannot be reconciled with current theories postulating a veridical analysis of the OF. We tested the model's predictions by asking observers to passively or actively view the local OF produced by a rotating planar surface. Results from these experiments, which will be illustrated at the present conference (Mancuso et al., VSS 2012; Fantoni, et al., VSS 2012), confirm the predictions of the model. Our findings provide further empirical evidence that the perceptual interpretation of the OF discards extraretinal signals of linear egomotion.

56.456 Assessing extra-retinal signal magnitude in the perception of depth from motion parallax

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While there is abundant psychophysical and neurophysiological evidence for an extra-retinal pursuit signal disambiguating the perception of depth from motion parallax, we note two conditions producing unambiguous depth where the eyes remain stationary within the orbit. The common feature of both is that the oculomotor system presumably generates an internal pursuit signal to countermand either translational vestibular ocular response or optokinetic response (OKR). Here we employ the transducer-corrected version of the Motion/Pursuit Ratio (Nawrot et al., VSS, 2011), along with the perceived depth of motion parallax stimuli, to determine the magnitude of the internal pursuit signal generated to maintain fixation against a large OKR inducing background. Observers performed comparisons of perceived depth magnitude between motion parallax and binocular stereopsis stimuli. A Stereographics Z-screen provided ocular separation for stereo stimuli and monocular viewing of the parallax stimuli. Both stimuli remained stationary on the monitor with fixation enforced with an eye-tracker. Parallax stimuli had a 41 x 25 deg OKR-evoking background of square-wave grating (0.25 cyc/deg) translating leftward or rightward at 5.5 or 11 deg/sec. Stereo stimuli had a stationary grey background. Parallax stimuli were quantified by maximum translation velocity of the stimulus dots ($d\theta$: 0.09 - 0.55 deg/sec). Stereo stimuli had a range of disparities (1.5 – 15 min). For each $d\theta$ value, a point of subjective equality (PSE) was estimated from the psychometric function, giving the amount of binocular disparity producing the equivalent magnitude of perceived depth from motion parallax. Depth from motion parallax was unambiguous suggesting that an internal pursuit signal was being generated to countermand the OKR. However, the two different OKR background velocities generated the same perceived depth magnitude for each of the $d\theta$ values. This result suggests that the two different OKR background stimulus velocities evoked identical internal pursuit signals.

Acknowledgement: NIH P20 RR020151.

56.457 Learning reorganizes the cortical circuits involved in depth perception: evidence from human TMS

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Judging the position of objects embedded in noise (coarse task), or fine differences in the depth position between objects (fine task) is thought to rely on dorsal and ventral processing, respectively. However, neurophysiological studies suggest that training on fine depth discriminations alters the processing of coarse depth in dorsal brain areas (Chowdhury & DeAngelis, doi: 10.1016/j.neuron.2008.08.023). Here we use online repetitive transcranial magnetic stimulation (rTMS) to test whether training reorganizes depth processing in the human brain. In particular, we ask whether parietal cortex is critical for judging depth position in noise before but not after training on a fine depth discrimination task. We tested observers' (n =12) ability to judge whether a central plane was in front or behind the surround before and after training on the fine task. Task difficulty was manipulated by altering signal-to-noise ratio (coarse task) or the disparity difference between the center and surround (fine task) using the QUEST staircase procedure. rTMS (5 pulses at 10Hz; 60% intensity) was applied over the left (P3) or right (P4) posterior parietal cortex (PPC) as well as a control site (Cz). Stimulation sites were tested on separate days (counterbalanced for order across participants) during pre- and post-training tests of the coarse task. Before training, performance on the coarse task was significantly worse during P3 stimulation compared to other sites, suggesting critical involvement of left parietal cortex in coarse depth judgments. In contrast, after training performance on the coarse task did not differ among stimulation sites, suggesting that training reduces the involvement of parietal cortex in coarse depth judgments. These findings suggest that learning reshapes the cortical network engaged in depth perception. In particular, training on fine judgments may enhance the representation of target features that in turn facilitate target detection from noise in the context of a coarse task.

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 See page 3 for Abstract Numbering System

56.458 **Neural correlates of ground plane perception revealed using multivariate pattern analysis**

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The ability to rapidly decode the 3D structure of a scene is a crucial ability for navigation and survival. To accomplish this, the brain has to translate two-dimensional images on the retina into three-dimensional percepts. Human depth perception relies on both binocular and monocular visual cues. Here, we investigated neural processing of monocular depth cues, produced by a textured ground plane, using multivariate pattern analysis of fMRI data. In separate scanning sessions, subjects were presented with two stimulus configurations: lines arranged either such that they formed a texture gradient leading to a depth percept of a receding ground plane, or randomly distributed such that no ground plane was perceived. Both stimulus configurations were present in each session, but line orientation differed between the two sessions. Thus there were four stimulus types: ground planes defined by vertical or horizontal lines, and scrambled vertical or horizontal lines equated for low-level image properties. We performed cross-categorical classification by training on lines of one orientation, and testing on the other. This was done to identify areas distinguishing the presence or absence of a ground plane, without relying on low-level stimulus differences. A searchlight analysis revealed a network of areas where it was possible to classify the presence of a ground plane independent of the orientation of the stimulus elements, including clusters in the superior and middle temporal and frontal cortices, as well as fusiform gyrus. Unlike within-orientation classification, cross-categorical classification did not occur in early visual cortex, which suggests that it did not rely on image-level features. This conclusion was further supported by an ROI-analysis revealing that cross-classification was not possible within V1, V2 or V3. These results support the existence of a wide-ranging network of brain areas dedicated to processing depth information derived from monocular cues.

56.459 **Statistics of three-dimensional natural scene structures**

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Generating a detailed percept of the three-dimensional (3D) scene underlying any visual stimulus is the most important task of natural vision. It has long been suggested that the visual system uses a set of modules to derive 3D information via complex image-based processing. However, missing in these approaches is a full understanding of the extraordinarily complex 3D natural scene statistics. In this work, we acquired a large set of high-resolution 3D natural scenes and examined the statistics of 3D natural scenes. We first sampled a large number of scene patches (~2 degrees of visual angle) from the database and fitted the 3D data in the patches to a concatenation of 8th order polynomial functions. We found all the 3D natural scene patches that had distinctive distributions of ranges (referred to as 3D natural scene structures). Two 3D scene patches were deemed to have the same distributions of ranges if they can be transformed to each other by an affine transform (displacement, rotation, and scaling). The rationale is to remove the variations in ranges due to uniform changes in viewing angles and surface shapes. Finally, we examined the occurring frequencies of these structures and their compositional patterns in natural scenes and developed a probabilistic model for each of them. To demonstrate the utilities of these 3D natural scene structures, we used them to estimate 3D scenes from 2D images and to categorize 3D natural scenes. Our results showed that accurate 3D vision from a single monocular view is achievable in many situations and that near-human performance can be achieved on categorizing 3D natural scenes with the obtained structures. We thus conclude that the 3D natural scene structures obtained here capture faithfully the extraordinarily complex 3D natural scene statistics in a way that supports a range of tasks of natural vision.

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56.460 **A Bayesian Approach to the 3D Aperture Problem**

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The 3D aperture problem occurs when a moving 3D object is viewed binocularly through a circular aperture so that endpoints of the object's oriented lines or edges remain occluded. Perception of local velocities for these ambiguous stimuli may reveal important visual processing characteristics of 3D motion. Here we investigate how the human visual system solves the 3D aperture problem in a Bayesian framework. Our model establishes likelihoods from (orientation) disparities and combines them with a zero disparity prior. The resulting orientation estimates provide the input for velocity constraints in a binocular viewing geometry. Perceived velocity is then inferred by combining the velocity constraints with a conjugate prior that incorporates the observer's prior knowledge of 3D motion. Thus, our Bayesian inference model estimates two free parameters: the first reflects uncertainty in disparity and the second uncertainty in motion processing. In an psychophysical experiment using a two-screen Wheatstone configuration, an oriented line was shown through a circular aperture so that line endpoints remained occluded. The stimulus line moved on a trajectory in depth while its orientation was set to $pm 45^circ$ (90^circ in a control) from horizontal at a binocular viewing distance of $55cm$. The slant in depth of the line was randomly varied across trials with orientation disparity ranging between -6^circ to $+6^circ$. In an open-loop adjustment task observers repeatedly adjusted tilt and slant of a probe to indicate perceived line motion direction. Adjustments from four observers gave comparable results and the model estimates revealed large uncertainty in orientation disparity but small uncertainty in motion processing. This suggests that observers resolve the 3D aperture problem by approximating a vector normal solution with small but systematic contributions from orientation disparity processing.

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Color and light: Lightness and brightness

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

56.501 **Relative brightness in natural images depends upon object size, not visual angle.**

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When identical achromatic test disks are placed on grayscale images of natural scenes, the disks placed in low luminance portions of the image appear brighter than the disks placed in higher luminance portions of the image. Shapiro and Lu (2011) demonstrated that the relative brightness can be accounted for by removing low spatial frequency content from the image. Here, we examine whether the visual system filters the amount of low spatial frequency content in terms of object units (i.e., relative to the size of the disks) or in terms of retinal units (i.e., set at a fixed visual angle). Observers ranked the perceived brightness of seven physically identical test disks placed on grayscale images of natural scenes. Five disk diameters were used (20, 40, 80, 120, or 160 pixels), and each observer viewed the images from four distances (60, 100, 200, 300 cm). A single parameter model controls the amount of low spatial frequency content removed from the image (cut-off frequency); we report the correlations (r) between observer rankings (perceptual values) and rankings of the disks' pixel (i.e., physical) values as a function of the cut-off frequency. The correlation values typically peak with r > 0.85 when the cut-off frequency is at or greater than the pixel size of the disks; for each disk size, the peak correlation occurs at the same filter level regardless of viewing distance. Perceived brightness of objects embedded in natural scenes is therefore independent of viewing distance, based not on the absolute size of objects on the retina, but on their size within the image. Our results suggest that brightness perception involves scale invariant computations of object properties, from which the amount of low spatial frequency content filtered from the image is derived.

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56.502 **The optimal estimator of lightness**

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When observers match the color of natural objects they base their judgments on the brightest parts of the objects. In the present work we test whether this behavior is an effective strategy for lightness estimation. The luminance of diffusely reflecting surfaces is proportional to the cosine of the angle between the surface normal and the direction of the incident light. However, the complex interaction between object geometry and natural light fields can hardly be treated analytically. We resorted to a physical-based rendering simulation to find the most robust estimate of the objects' reflectance. Using the software RADIANCE interfaced with a MATLAB toolbox, we rendered a set of virtual objects under a large variety of different viewing and illumination conditions using simulated natural light fields. Each view was rendered with different values of reflectance. For each rendered object, we calculated the percentiles of the radiance distribution as potential lightness estimates. We found that the distribution of the standard deviations for each estimate has approximately an inverted U-shape with minima for the darkest and the brightest object regions. Given that the dependency of the luminance on the incident light direction has to be maximal for the most illuminated parts of the objects, the sharp drop in variability for the extremely bright portions of the objects can only be due to a reduction in the variability of their orientation within the light field. Intuitively, this means that for most natural objects there is nearly always a region that is close to perpendicular to the direction of the light source. Results of an ROC-analysis show that reflectance discriminability increases with the luminance of the object region which is compared. Results of both analyses indicate the most illuminated regions are most diagnostic of the object´s reflectance.

56.503 **Stain or shadow? Perception of a dark spot on textured backgrounds**

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When distinguishing illumination from reflectance edges, both blurriness of an edge and textural continuity across an edge are generally used as clues for interpreting the edge as an illumination edge. However, we found that, when these clues are combined, i.e., when a dark spot having a blurred edge is placed on textured backgrounds, the spot appears stained or painted rather than differently illuminated (Sawayama & Kimura, VSS2011). To elucidate the visual mechanism underlying this effect, this study analyzed spatial properties of a real shadow and stain, and investigated whether and how they are used for luminance edge interpretation. Wooden boards and cloths were used as textured backgrounds and onto these backgrounds a circular shadow was cast or a small amount of water was dropped to create shadow and stain stimuli. Then, photographs of the stimuli were taken under consistent lighting condition. The image analysis showed that edge blur of stains tends to be narrower in width than that of shadows. However, rating experiments revealed that the difference in spatial profile was not used when distinguishing stains from shadows. Observers judged the images of both shadows and stains as differing in reflectance. This bias in perception for reflectance over illumination edges (i.e., stains over shadows) was much reduced when a light spot was projected in place of a shadow even if their spatial profiles were similar except for the difference in luminance polarity. These results can be understood if we take into consideration much more frequent occurrence of a dark stain (and a light spot) than a "spot shadow" (an isolated shadow with the shadow caster being out of sight) in natural scenes. The bias for stains in perceiving dark spots may reflect heuristic processing that identifies the most likely cause of luminance variation based mainly on luminance polarity of the edge.

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56.504 **Luminance range mapping in lightness computation: a novel role for attentional modulation**

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Our visual system is capable of operating over an enormous range of light intensities, from an absolute threshold of a few photons to light environments twelve orders of magnitude greater in average intensity. By comparison, the noise-limited operating range of a spiking neuron is about three orders of magnitude. Significant signal compression is therefore required to map the range of environmental luminances into a neural rate code. Here I consider the problem of range mapping—also known as 'scaling' (Gilchrist et al., 1999)—in the context of lightness computation when scene luminances are interpreted as surface reflectances (e.g. Gelb staircase). I argue that range mapping is influenced by a combination of neural adaptation mechanisms functioning at different levels of the visual hierarchy and on different spatial scales, working in concert to avoid saturating higher-level neural mechanisms that represent surface reflectance. An example of a local adaptation mechanism is luminance ratio encoding, which is known to occur early in visual processing. Psychophysical data suggests the existence of a second local process that converts ratios to logarithms in order to avoid saturation at a subsequent processing stage, where local contrasts are perceptually integrated across space. At a somewhat larger spatial scale, contrast gain control functions to further avoid saturation in the mechanisms that spatially integrate contrast. Finally, I consider the question of where attention fits into this scheme. Several recent studies (Arend & Spehar, 1993; Rudd, 2010; Economou, ECVP 2011) demonstrate that lightness percepts can be influenced by instructions (attention). I argue from the experimental data that attentional selection influences perceived lightness at a processing stage prior to the stage at which contrast gain control operates and that this positioning in the sequence of lightness computations makes sense in that it protects the neurons representing reflectance from being saturated by unattended image content.

56.505 **Brightness induction by contextual influences in V1: a neurodynamical account**

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Brightness induction is the modulation of the perceived intensity of an area by the luminance of surrounding areas and reveals fundamental properties of neural organization in the visual system. Several phenomenological models have been proposed that successfully account for psychophysical data (Pessoa et al. 1995, Blakeslee and McCourt 2004, Barkan et al. 2008, Otazu et al. 2008). Neurophysiological evidence suggests that brightness information is explicitly represented in V1 and neuronal response modulations have been observed following luminance changes outside their receptive fields (Rossi and Paradiso, 1999). In this work we investigate possible neural mechanisms that offer a plausible explanation for such effects. To this end, we consider the model by Z.Li (1999) which is based on biological data and focuses on the part of V1 responsible for contextual influences, namely, layer 2–3 pyramidal cells, interneurons, and horizontal intracortical connections. This model has proven to account for phenomena such as contour detection and preattentive segmentation, which share with brightness induction the relevant effect of contextual influences. In our model, the input to the network is derived from a complete multiscale and multi-orientation wavelet decomposition which makes it possible to recover an image reflecting the perceived intensity. The proposed model successfully accounts for well known pyschophysical effects (among them: the White's and modified White's effects, the Todorović, Chevreul, achromatic ring patterns, and grating induction effects). Our work suggests that intra-cortical interactions in the primary visual cortex could partially explain perceptual brightness induction effects and reveals how a common general architecture may account for several different fundamental processes emerging early in the visual pathway. Keywords: Brightness induction, primary visual cortex, horizontal intracortical connections.

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56.506 **Bias and precision in the perception and memory for stimulus lightness**

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PURPOSE. Although color memory has been extensively studied, its relationship to color perception is controversial. We investigated this relationship for achromatic color by characterizing the bias and precision for both perception and memory for lightness within the same experimental para-

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digm. METHODS. The task was lightness discrimination. On each trial, a reference and a test stimulus were presented horizontally on either side of fixation for 500 ms, either simultaneously or separated by 2.5 seconds. The observer indicated which one appeared lighter. Reference stimuli were either decrements or increments relative to their background. The test stimulus background matched the reference background (symmetric condition) or was lighter (asymmetric condition). Interleaved staircases controlled the intensity of the test stimulus. Background and delay conditions were blocked. Points of subjective equality (PSE) and discrimination thresholds were determined from a cumulative Gaussian fit to the proportion lighter data. We defined bias as the shift of the PSE relative to the reference stimulus, and precision as the reciprocal of the threshold. RESULTS. 1. Bias: The asymmetric background caused a shift in the PSEs in the simultaneous comparison as expected. For both increments and decrements, the background bias was largest for low-contrast reference stimuli (~20%) and decreased with increasing reference contrast. Interestingly, there was a bias of up to 15% in the symmetric delayed condition, but the pattern across reference stimuli was more complex: in some cases the bias had an opposite sign for decrements and increments. Finally, the delay and background biases approximately added in the asymmetric delayed condition. 2. Precision: Background did not have a measurable effect on thresholds in the simultaneous condition. The delay caused an increase in thresholds for both decrements and increments on both backgrounds. CONCLUSION. Under these experimental conditions, memory for lightness appears to be both biased and less precise relative to perception.

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56.507 **Filling in or filling out – color in the center of gaze**

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Uniform fields appear uniform in color despite spatial variations in spectral sensitivity owing to factors such as macular pigment screening and the absence of short-wave cones in the central fovea. We examined how color appearance varies with field size and spatial delineation to explore how the fovea and near periphery are weighted. Chromatic sensitivity is best in the fovea, and under some conditions can "fill out" to affect color percepts in the periphery. Conversely, under many conditions color at peripheral borders "fills in" to alter percepts within the field. We used blue spots presented on a CRT, chosen because when small they look distinctly different in the fovea and periphery. Appearance was assessed by matching perceived color across locations. For desaturated blue spots there is a marked shift in hue, so that fixated dots appear more purple. Consequently the Abney effect (changes in hue with saturation) is substantially stronger in the fovea. This hue shift persisted for spots up to 2 deg and thus cannot be accounted for by small-field tritanopia alone, though both S-cone and macular pigment variations may contribute. As field size is increased the hue shifts toward the peripheral percept. However, similar effects were found for uniform fields delimited by sharp luminance borders or for fields which were instead tapered with a Gaussian envelope. Moreover, the perceived shifts in hue were also substantially stronger when the spots were isoluminant with the background. Our results suggest that the color percept for large fields is more strongly weighted for the near periphery, but that this filling in is not determined by the chromatic signals at luminance borders.

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56.508 **The phantom spokes illusion**

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When a regular array of small bright dots is rotated in the image plane, dark spoke-like bands are seen, which are aligned with the array. The spokes are only seen when the pattern is in motion, and have an ephemeral, shimmering appearance, similar the that seen in certain op art designs. This illusion was first observed by the author when handling a 2′ x 4′ sheet of diffusing plastic intended for a flourescent lighting fixture. For a sheet with square cells, a cross is seen aligned with grid, with a somewhat fainter cross appearing at 45 degrees to the grid. For a sheet with triangular cells, 6 spokes are seen. The effect can be seen equally well by rotating an LCD display monitor (e.g., a laptop screen) displaying a regular array of bright dots. The illusion can be explained by an early compressive nonlinearity, which depresses the average response in regions where the motion causes neighboring dots to follow a common path, relative to off-axis regions where the smeared dots fill the space uniformly.

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56.509 **Contrast Polarity Preservation's Role in Perception: Explained and Unexplained Stimuli**

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Roncato and Casco (2003) had shown that in situations where the Gestalt principle of good continuity is put into conflict with preservation of contrast polarity (CP) the perception that preserves CP prevails. Parlangeli and Roncato (2010) have studied this question of preservation of contrast polarity more closely and have added an addendum to the rule. They have used stimuli consisting of a checkerboard of perpendicularly arranged rectangular bricks (white, gray or black) and draughtsmen—white, gray or black disks placed at the corners of the bricks. This study using the stimuli has caused them to add an addendum to the rule of CP-preserved path-conjunction binding: if there are two contour completions that preserve the CP, the one with the higher contrast will prevail. Parlangeli and Roncato find that for certain shades of the disks and bricks the perpendicular lines of the checkerboard appear strikingly to be slanted or undulating. Here we consider all possible arrangements of relative magnitudes of checkerboards consisting of bricks of two different shades and disks of two shades as well as such arrangements with widely varying differences in the magnitude of brightness. We have found a number of cases where the perception is not explained by the rule and addendum of Casco, Parlangeli and Roncato, and a case where preservation of "distant" as well as local CP plays a role in perception. Further study of the previously known cases, and the new exceptional unexplained stimuli we have found warrant further study.

56.510 **When luminance increment thresholds depend on apparent lightness**

Marianne Maertens[1](marianne.maertens@tu-berlin.de), Felix Wichmann[2]; [1]Technische Univeristät Berlin and Bernstein Center for Computational Neuroscience Berlin, [2]Bernstein Center for Computational Neuroscience Tübingen and Wilhelm Schickhard Institute for Computer Sciences Eberhard Karls University Tübingen

The just noticeable difference (JND) between two stimulus intensities increases proportional to the background intensity (Weber's law). It is less clear, however, whether the JND is a function of the proximal or perceptual stimulus intensity. In the domain of achromatic surface colors the question would translate to whether the JND depends on local luminance or surface lightness. In the laboratory using simple stimuli such as uniform patches, proximal (luminance) and perceived intensity (lightness) often coincide. Reports that tried to disentangle the two factors yielded inconsistent results (e.g. Heinemann, 1961 JEP 61 389-399; Cornsweet and Teller, 1965 JOSA 55(10) 1303-1308; Zaidi and Krauskopf, 1985 Vision Res 26 759-62; McCourt and Kingdom, 1996 Vision Res 36 2563-73; Henning, Millar and Hill, 2000 JOSA 17(7) 1147-1159; Hillis and Brainard, 2007 CurrBiol 17 1714-1719). Following a previous experiment (Maertens and Wichmann, 2010 JVis 10 424) we measured discrimination thresholds in the Adelson checkerboard pattern for two equiluminant checks which differed in lightness (black vs. white). Discrimination performance was measured in two conditions: in the 'blob' condition, the increment was a two-dimensional gaussian centered on the check, in the 'check' condition, the increment was a constant that was added to the entire check. Performance was assessed in a 2-interval forced-choice and a yes-no task. In the 'blob' condition thresholds were indistinguishable between equiluminant checks and did not differ between the tasks. In the 'check' condition thresholds differed between equiluminant checks and were elevated for the lighter one. This was true for the yes-no task and to a lesser extent in the 2-IFC task. We think that these results require discussion beyond the question for the appropriate type of increment. We believe that the visual system might respond fundamentally different to light emanating from meaningful surfaces and to isolated spots of light.

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56.511 Alterations of the contrast gain during normal aging: a dissociation between the Magnocellular and Parvocellular signatures for old and very-old groups

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Functional changes in normal aging for both Magnocellular (M) and Parvocellular (P) pathways have been reported, with a greater loss for the P system (Elliot & Werner, 2010, JOV). The aim of the study was to investigate the late development of the two systems in old age by comparing two aged groups. A short version of the original paradigm (Pokorny and Smith, 1997, JOSA) has been used in 18 young (19-34), 25 old (61-74) and 11very old (75-80) observers. They had to discriminate the location of the higher luminance square with in a 33-msec four-square-array. In the steady-pedestal condition (M-bias), the array was preceded and followed by a four identical squares pedestal whereas, in the pulse pedestal condition (P-bias), the array was presented alone on a gray background. Three target luminance discrimination thresholds were collected for each of the 6 experimental conditions (order counterbalanced): 3 pedestal-contrasts (63%; 70%; 75%) x 2 pedestal-conditions (pulse and steady) using an adaptive staircase procedure. The results showed a higher increase of threshold when pedestal contrast increased in the pulse-pedestal than in the steady-pedestal condition, consistently with the original results in young adults. The main result was a double interaction between group, pedestal contrast and pedestal-condition : There was a huge increase of threshold with aging in the pulse-pedestal condition, with no differences between the two aged groups, whereas in the steady-pedestal, there was a slight increase in threshold in old age and a larger increase in threshold in the very-old aged group. These results are consistent with a dissociation in the evolution of the two systems with aging. Under the conditions tested, the functional loss for the P pathway, tough larger than the M pathway, seems to be stable from 60-year-old, although the M pathways still deteriorated after 75-year-old.

56.512 Both 3D Orientation and Local Contrast Affect Surface Lightness

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The ability to discount spatial variation in illumination is central to achieving lightness constancy in natural scenes. There is evidence that the visual system uses the 3D relationship between surfaces as one cue to the likelihood that they share a common illumination (Gilchrist, 1980), but how this cue interacts with the information provided by the luminance statistics of various image regions is not understood. To investigate, we presented subjects with computer-simulated 3D grayscale scenes, using a stereoscopic display. Two planar Mondrians were rendered in a roof-like arrangement. This roof was oriented in 3D such that its ridge formed a horizontal line in the cyclopean image, and each Mondrian appeared tilted away from the observer at a 45° angle. The upper Mondrian contained patches with higher luminances (17 to 262 cd/m2) than the lower one (0.6 to 9.5 cd/m2). On each trial, a target patch was presented at one of four possible tilts. The target could lie flat against either Mondrian, or extend outwards from the horizontal ridge at a tilt that made it coplanar with either Mondrian. Nine target luminances spanned the range 0.6 to 262 cd/m2. Subjects matched the lightness of the target patches to a grayscale Munsell palette that was presented in a separate viewing chamber. The data establish luminance-to-lightness mappings for each target tilt. Both the 3D orientation of the target and its immediate surround in the image affect the luminance-to-lightness mappings: the target appears darker both when its immediate surround is more luminous and when it is co-planar with a more luminous Mondrian. The magnitude of the effect of 3D orientation was about one Munsell step — large enough to be easily measurable, but smaller than has been reported for similar experiments performed using real illuminated surfaces (Gilchrist, 1980).

56.513 Effective ranges of shorter durations yielding greater simultaneous contrast of brightness and color

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Perceived brightness and color can be affected by surrounding light. We previously demonstrated (Kaneko & Murakami, VSS, 2011) that these illusions of simultaneous brightness contrast and color contrast are both greatly enhanced when the stimulus is flashed briefly (for a single video frame), compared to the illusions seen in longer-lasting stimuli. We argued that different processes were involved in the illusions depending on stimulus duration. In the present study, we systematically varied the stimulus duration and examined the temporal dynamics of these illusions to see how quickly the switch from one process to another occurs. We used the method of adjustment to measure the perceived brightness or color of a test disk (radius 0.5 deg) positioned at the center of a larger annulus (radius 8.25/5 deg) of various luminance or color. The colors of the annulus used in this color matching experiment were constrained along the cardinal axes on the equiluminant plane in DKL color space. The luminance/color of the test was the same as that of the background and was kept constant throughout session whereas the duration of the larger annulus was varied from 10 to 640 ms. Subjects were requested to adjust the luminance/color of a comparison disk surrounded by luminance noise to match the brightness/color of the test disk. The illusion strength showed a sharp drop with increasing stimulus duration and rapidly reached a steady level. This temporal profile was found in both brightness matching and color matching results. We fitted an exponential decay function to each profile and obtained time constants for individual data. The time constants in the brightness matching data were longer than those in the color matching data. This suggests that although in principle both illusions show enhancement at short durations, the underlying mechanisms that bring the enhancement are not necessarily the same.

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56.514 Relationship between perceived lightness and the luminance statistics of the surrounding natural image

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Perceived lightness of a surface in an image is influenced by the contexts of the surrounding images in addition to the surrounding luminance of perceptually adjacent area. One possible explanation for this would be a higher process of visual system recognizes the illuminant condition of the image and then affects the lightness perception. However, there could be another explanation that a lower process utilizes some statistics of the image's luminance distribution having a relationship with the illuminant condition in the scene for deciding the perceived lightness directly. In this study, we investigated the relationship between the perceived lightness of a surface presented on natural images and the statistics such as the variance, skewness and maximum value of luminance distribution. In addition, we conducted a field measurement of illumimance to examine whether the illuminant condition in our environment relates to some statistics of the luminance distribution of the image. In this experiment, observers matched the perceived lightness of a test patch presented on the natural images to that of a comparison patch presented on a uniform gray background. The natural scene images were taken in indoor, outdoor and forest environments. We also used inverted and scrambled images to separate the influence of recognized image contents from that of luminance distribution. Results showed that there were correlations between the perceived lightness and the variance and skewness of luminance distribution of the images. The field measurement revealed a significant correlation between the perceived lightness and the illuminance measured in the forest environment, but no significant correlation between the measured illuminance and either the variance or the skewness of luminance distribution in all of the environments used. Theses results suggest that the visual system might refer some statistics of luminance distribution, however, they seem more complex than mere variance or skewness for lightness perception.

56.515 Black rooms seen through a veiling luminance: gradient amplitude vs highest luminance

Stephen Ivory[1](southorange21@yahoo.com), Alan Gilchrist[1]; [1]Psychology, Newark, Rutgers University

Gilchrist and Jacobsen (1984) showed that all-black rooms appear darker than all-white rooms because the luminance gradients are steeper in the black room due to the lack of mutual illumination. Gilchrist and Ivory (2011) showed that reducing the luminance amplitude of the image by viewing

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the black room through a veiling luminance makes the room appear white. To compare the relative strength of gradient amplitude and highest luminance effect, a white square was added to the black room viewed through a veil. If highest luminance governs, the room will appear darker. However, if the low gradient amplitude dominates, keeping the room white, the white square should look self-luminous. Fifteen observers viewed a small 40 cm cubic room with all walls and random objects painted matte black. The white square was placed on the face of a large cube. The veil, which filled the entire aperture through which the room was seen, was created by reflecting a rear-illuminated sheet of acrylic onto a clear sheet of glass through which the room was viewed. Mean Munsell match for the room was 8.6, marginally darker (p=.06) than the room without the white square. All fifteen observers reported the white square as self-luminous and three reported seeing the veil. This suggests that gradient amplitude is more influential in determining the lightness of the room than highest luminance. In a second experiment, the white square was replaced with a white 3D object. The room appeared significantly darker (Munsell 7.1); only one observer reported the object as self-luminous; and seven observers saw the veil. This suggests that the shape-from-shading gradients in the object prevented self-luminosity, yielding darker matches for the room.

Acknowledgement: NSF (BCS-1027093) NIH (1R25GM096161-01)

56.516 **Perceptual consequence of normalization revealed by a novel brightness illusion**

Sang Wook Hong[1](shong6@fau.edu), Min-Suk Kang[2]; [1]Department of Psychology, Florida Atlantic University, [2]Department of Psychology, Vanderbilt University

Despite advanced image processing technology, digital cameras generally cannot handle the enormous range of light intensity that varies approximately 6 log-unit in everyday life. The human visual system is renowned for its dynamic regulation, rendering us to discriminate or detect subtle differences among visual inputs in the dynamically changing environment. Here we present a novel and strong illusory brightness perception that reflects neural mechanisms underlying this dynamic regulation of sensory inputs: motion signal from neighboring objects modulates perceived contrast of both the moving and the stationary objects against their background. Consequently, the stationary objects appear different from the moving objects even though both have the same physical light intensity. Experiments reveal that figure-ground segmentation, adaptation, attention, and motion-induced blindness cannot explain this illusion. Instead, normalization accompanied by motion signal is a plausible account for the illusory changes in perceptual experiences, observed in both stationary and moving objects. This novel brightness illusion suggests that brightness of an object is influenced by not just variations in surrounding light (i.e. simultaneous contrast), but also motion-induced neural signal in the context.

56.517 **The role of feedback and long-range horizontal connections in brightness**-related responses in visual cortex: a computational model

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Rossi et al. (1996, Science) reported a drop-off at 4 Hz in the modulation amplitude of neural responses to large (up to 14 degrees) simultaneous contrast stimuli in cat striate cortex, as the temporal frequency of the luminance of flanking patches increases, while the luminance of the central patch covering the neurons' receptive fields is held constant. Their results indicate that the modulation may involve slow processing of information over a visual area that is sufficiently large to require that cortical magnification be considered in any explanation. To explore the possible roles that cortical feedback and horizontal connections may play in modulating neural responses, we develop a model of visual cortex that incorporates constraints including the lengths and conduction speeds of both inter-area feedback and intra-area horizontal connections, the cortical magnification factor, and the sizes of receptive fields at different eccentricities. Our model shows that it is very unlikely that intra-area horizontal connections alone can account for the Rossi et al. data. (1) We find that the cortical distance of a monosynaptic horizontal connection is smaller than the cortical distance between the neuron whose receptive field is covered by the central patch and the nearest neuron whose receptive field is covered by the flanking patch (Gilbert & Wiesel, 1989, Journal of Neuroscience). (2) Functionally, the response invoked by horizontal connections is limited to a smaller cortical region than is needed to account for the lateral modulation of neural responses to large simultaneous contrast stimuli (Das & Gilbert, 1995, Nature; Nauhaus, et al., 2009, Nature Neuroscience). Given the limited spatial range of feedforward projections from LGN to striate cortex, our results indicate that inter-area feedback is involved in the long-range modulation of contrast responses in striate cortex, as opposed to the view that spreading activity within that cortical area is sufficient.

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Motion: Phenomena and Illusions

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

56.521 **Involuntary attention can modulate the disappearance in motion-induced blindness**

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Motion-induced blindness (MIB) is a phenomenon in which salient stationary (or slowly moving) objects spontaneously disappear and reappear when superimposed onto a globally moving pattern (Bonneh et al, 2001 Nature 411 798 - 801). In MIB, it remains an open question whether paying attention to these objects will increase or decrease their disappearance, as conflicting findings have been reported from previous studies (Kawabe et al.,2007; Geng et al.,2007; Scholvinck & Rees, 2009). In the present study, we investigated the attention effect on MIB with four experiments. Experiment 1 and 2 relied on the classic finding that onset draws attention more than color change. In Experiment 1, immediately following the observers' reports of disappearance of targets, either the color of one of the three distractors around the target was changed (color change condition) or a new distractor abruptly appeared near the target (onset condition). It was found that the duration of target disappearance was significantly shorter in onset condition than that in color change condition. Experiment 2 was identical to Experiment 1 except that distractors in Experiment 2 were in the opposite side. The result was opposite to that in Experiment1: namely, the duration of target disappearance was significantly longer in onset condition than that in color change condition. In sum, Experiment 1 and 2 suggested that directing attention toward target led to its shorter disappearance duration, whereas withdrawing attention away from target led to longer disappearance duration. In Experiment 3-4, we further tested this notion by comparing looming and receding stimuli (Experiment 3) and by comparing motion and color change (Experiment 4), and obtained consistent results. In conclusion, more attention causes less target disappearance in MIB.

Acknowledgement: This research was supported by RGC Grant, 446110, and RGC Grant 446411 from the Hong Kong Government awarded to LH.

56.522 **Motion parallax, pursuit eye movements and night vision goggles**

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Single optic night vision goggles (SONVGs) provide important visual function in dark, vision-less conditions. However, the visual function they do provide is greatly constrained. For instance, the field of view available through the optics is restricted and binocular stereopsis is lost. Even though monocular depth cues, including motion parallax, are still available, SONVG users often complain of perceptual problems involving depth and spatial relationships (Wiley, 1989). Here we investigate the hypothesis that motion parallax is affected with SONVGs due to interference with the pursuit signal (necessary for the unambiguous perception of depth from motion parallax; Nawrot & Joyce, 2006) in order to maintain ocular alignment with the SONVG optics. The study used a free-viewing task with a modified Howard-Dolman apparatus in which the participant used a string to align two identical black rods in the frontal-parallel plane. Unaided binocular (UB), unaided monocular motion parallax (UM) and night vision goggle monocular motion parallax (NV) viewing conditions were compared to psychophysically assess the accuracy of depth perception in each. Each participant completed all three conditions. In both monocular motion parallax conditions the horizontal movements of the right eye were measured using a Skalar IRIS IR eye-tracker as the participant performed the task. The largest mean offset and standard deviation was observed in the NV condition (4 orders of magnitude larger than the UB condition), fol-

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lowed by the UM condition (2 orders of magnitude larger than the UB condition) and UB condition. Eye movement recordings were analyzed for the magnitude of smooth pursuit eye movements. Smaller magnitude pursuit eye movements were observed in the NV condition as compared to the UM condition. These findings suggest that disambiguation of depth using motion parallax information is hindered due to smaller or absent eye movements in the NV condition relative to the UM condition.

Acknowledgement: This work was supported by a Centers of Biomedical Research Excellence (COBRE) grant: NIH P20 RR020151.

56.523 **Behavioral measurement of RDK velocity discrimination thresholds in the tree shrew.**

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Tree shrews are fast-moving diurnal mammals with cone-dominated retinas and well-developed visual systems. They are considered to be a prototype of early primates. Often the subject of anatomical, physiological and imaging studies, behavioral assessment of their visual capabilities is limited. Previously we reported psychophysical measurements of spatial CSF (Petry et al., 1984); color vision (Petry & Kelly, 1991) and temporal vision (Callahan & Petry, 2000). Here we report psychophysical assessment of velocity discrimination thresholds. Two adult tree shrews (Tupaia belangeri) were trained in an operant chamber on a 3-alternative forced-choice task to detect a velocity difference in one of three stimuli (an "odd-ball" task). The stimuli were computer generated random dot kinematograms (RDKs; Vision Research Graphics) consisting of white dots on a black background (dot size 3x2 pixels). Each stimulus subtended 25.5deg visual angle when viewed at 15.5cm. A response was registered when the animal touched the stimulus. Correct responses were rewarded with fruit juice. Foil RDKs drifted at 90deg at 5 deg/sec. The oddball also drifted at 90deg, but at a higher velocity, starting at 15 deg/sec. Velocity of the oddball was varied trial-by-trial using a modified staircase technique. Frequency-of-seeing curves were calculated with threshold performance defined as midway between maximum performance and chance (see above references for more detail on the analysis). Results revealed Weber fractions of 1.0 and 0.9 for the two shrews. These values were about 1 log unit poorer than for human observers tested using the same apparatus, but were closer to values reported for cats (e.g., under roughly comparable conditions, Lomber et al., 2010 found fractions of about 0.5). Given the much smaller eye size and array of retinal neurons of tree shrews, their comparatively good velocity discrimination likely provides a necessary survival capacity related to their own fast movements and to those of their prey.

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56.524 **Visual Evaluation of Gesture Motion and Walking Difficulty Using Singular Value Decomposition**

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Problem. Singular value decomposition (SVD) was recently used on visual motion sequences in order to extract similarities and differences across human behavioral patterns (T. Ide and K. Inoue, SDM05, 571-576, 2005). In this study, we present a new method based on SVD for recognizing hand gesture motions and formulate a method for the quantitative evaluation of walking ability. This efficient method can be used to automatically analyze the walking patterns of individuals with impaired locomotor skills. Experiment. The experiment on gesture motion analysis focuses on five kinds of hand gestures: CH (Come here), GA (Go away), GR (Go right), GL (Go left), and CD (Calm down). Each motion pattern is represented by the left singular vectors of the SVD computed over the corresponding motion sequence. In order to compare a given test gesture pattern with the training gesture patterns, we propose to compute similarity using either gesture distances (SGD) or gesture vectors (SGV). In the experiment on walking analysis, in order to verify the usefulness of the SVD-based method, three levels of walking difficulty in the lower limbs are simulated by constraining the knee joint and ankle joint of the right leg. Result. In the hand gesture recognition task, the proposed method achieves a 90% accuracy level when similarity is computed with gesture distances. Recognition results indicate that the CH, GA, and CD gestures are all easily discriminated. For the walking analysis task, results show that the first few singular values computed from the acceleration of the shanks are inversely proportional to the constraint on the knee joint. These same singular values thus appear to be reliable indicators of walking difficulty. Acknowledgement. This work was partially supported by MEXT of Japan under Strategic Project to Support the Formation of Research Bases at Private Universities, 2008-2012., and ORDIST of Kansai University.

56.525 **Motion path misidentification in the periphery**

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Examination of motion illusions in foveal and peripheral vision have led to the ''feature blur'' hypothesis: the peripheral visual system combines features that the foveal visual system can separate (Shapiro, Knight, Lu, 2011, journal.pone.0018719). Others have hypothesized that processes that underlie crowding limit multiple object tracking. Here, we investigate the perception of motion paths of two objects that follow opposite rotational directions; we hypothesized that objects that follow the same path may produce misidentifications that depend on eccentricity. The stimulus consists of two 1-deg disks, one filed with a radial sine-wave pattern (concentric rings), the other with a tangential sine-wave pattern (spokes on a wheel); one disk rotates clockwise around a central point while the other rotates counter-clockwise. When viewed in the periphery (in some conditions), the disks do not seem to follow circular paths but rather appear as an elliptical jumble of the two disks; however, when one disk is made invisible, the remaining disk appears to travel in a circular path. We measured the critical size of the circular path (i.e., the size at which there is a transition between the percept of a circular path and jumbled ellipses) at five different eccentricities; the results showed that the critical size is equal to 0.291*eccentricity-2.67, which is similar to Bauma's law of crowding (slope between 0.1 and 0.5). In addition we have produced demonstrations that clearly show that the critical size of the circular path decreases when the relative contrast, color and spatial frequency of the two disks are dissimilar to each other (i.e., two disks seem appear to follow jumbled ellipses when they are similar, but follow circular paths when their features are different from each other). Conclusion: motion path misidentification in the visual periphery depends on eccentricity, similar in principle to Bauma's law in visual crowding.

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56.526 **Integration of motion signals in the absence of changes in spatial position**

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A moving object produces multiple motion signals at its edges; the visual system must organize (i.e., group) the motion signals associated with the object even though these signals can be separated over a considerable distance. Here we present a novel stimulus configuration for assessing the visual system's ability to organize disparate motion signals into the perception of illusory object motion. The stimulus for the first experiment consisted of a diamond (4.7 deg diagonal, static 50 cd/m2) bordered by four thin edges (.21 deg) and square background (14 deg); the luminance of the edges and the background modulate at 3 Hz. Similar to reversed-phi, motion signals are produced by phase differences between the modulation of the edges and background. Even though the diamond is physically stationary, it will appear to move upwards when the modulation for the top edges phase-leads the background and the modulation of bottom edges phase-trails the background (the diamond moves downward when the phase relationships are reversed). We measured an observer's ability to detect the direction of the diamond's motion as a function of 19 parametric phase combinations of edges and background at four modulation amplitudes. The four observers detected the object motion on a higher proportion of trials when the phase differences between edges and background increased and were able to consistently detect object direction with as subtle as a 10 deg phase shift between edge and background. Further demonstrations illustrate that luminance noise does not disrupt object motion as long as the phase relationship between edges and background remains the same. Conclusion: We introduce a powerful (and visually dramatic) new method for measuring motion integration and show that the visual system can integrate extraordinarily fine differences in temporal phase over large spatial distances.

Acknowledgement: Supported by NIH grant R15EY021008 to AGS

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56.527 **The Recovery of Shape from 3rd-order Counter-change Specified Motion vs. 1st-order Motion Energy**

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Visual information is often noisy and ambiguous. To overcome this, the visual system exploits multiple sources of information to resolve ambiguity. Here we investigate the use of different kinds of motion information to recover the shape of a displaced object from the noisy background of a random dot cinematogram (RDC). The ability to perceive shape-from-motion in an RDC depends on the ability to segregate the coherent motion of the object from incoherent background motion. The stimuli in Experiment 1 were two-frame RDCs; a rectangular figure is displaced and the background updated randomly. For half the trials, the contrast is reversed during the second frame, creating reverse-phi motion. Subjects indicated the perceived motion direction (left or right) and shape (tall or wide). Judgments could be based on either 3rd-order counterchange-specified motion or 1st-order motion energy when contrast was not reversed, but only on motion energy when it was reversed. Experiment 2 was identical except that triangular figures were displaced; shape discrimination was based on the triangles' orientation. Following Sato (1989), shape was easily discernible for small displacements in the non-reverse condition, but not in the reverse-contrast condition, for which reverse-phi motion is perceived in the direction opposite to the displacement. Differences in shape were weakly inferred from differences in reverse-phi motion strength between the flat and upright rectangles; this was eliminated when reverse-phi motion strength was balanced for the triangular shapes in Experiment 2. The results suggest that motion energy provides information that can inferentially aid simple shape discrimination, but is distinct from the non-reverse condition, for which a segregated figure can be perceived. We conclude that 3rd-order, counterchange-specified motion is the basis for perceiving shape-from-motion in the RDC. Its absence for motion in the reverse-phi direction is consistent with the "objectless" quality of 1st-order motion energy.

56.528 **Local form-motion interactions influence global form perception**

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Object motion perception depends on the integration of form and motion information into a unified neural representation. Historically, form and motion perception are thought to be independent processes; however, research demonstrates that these processes interact in numerous and complex ways. For example, an object's orientation relative to its direction of motion will influence its perceived speed (Georges, Seriès, Frégnac and Lorenceau, 2002). Here we investigated whether this local form-motion interaction influences global form processing. In experiment 1, we replicated the effect of orientation dependent modulation of speed. In experiment 2, we investigated whether the perceived speed of local elements could influence the perceived shape of a global object constructed from grouping of those elements. Results indicated that the orientation of local elements indeed influenced the perceived shape of a global object. We propose that inputs from local form-motion processes are one of perhaps many neural mechanisms underlying global form integration.

56.529 **The role of adaptation in Motion-induced Blindness: Evidence from a mask coherence manipulation**

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Sensory adaptation is believed to account for several perceptual phenomena, such as Troxler fading, although its role in the disappearance phenomenon of motion-induced blindness (MIB) has been a source of recent controversy. It has been proposed that relatively greater adaptation of stationary targets compared to dynamic moving masks makes the targets more prone to perceptual disappearance, and the finding that MIB rates increase as a function of time lends support to this adaptation account (Gorea & Caetta, 2009, J Vis). Here, we offer a novel test of the adaptation account by focusing on mask coherence. We recently showed that MIB decreases as the motion coherence of the mask increases (Wells, Leber & Sparrow, in press, Perception). This coherence effect could potentially be explained by the adaptation account, since masks with high coherence are more stable and thus more readily adapted, compared to masks with low coherence. That is, conditions with low mask adaptation are comparatively less adapted than the target and should thus yield greater MIB. Critically, the adaptation account predicts that the coherence effect should evolve over time, with little difference in MIB rates between low and high coherence conditions at the beginning of the trial (before adaptation has occurred) and larger differences between these conditions at later points in the trial. To evaluate this prediction, we examined MIB rates across four levels of mask coherence (0%, 33%, 66%, and 100%), dividing the trials into six consecutive 5-second bins. Results showed an interaction between coherence and bin, such that MIB rates in the first bin did not vary across coherence but dramatically diverged between the levels of coherence at the later bins. These results are consistent with the account that adaptation contributes to the phenomenon of MIB.

56.530 **Features bias correspondence in apparent motion over short distances in the Ternus display but long distances in split motion**

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The role of features in resolving the correspondence problem (maintaining object identity as the object or the eyes move) is an open debate. Many studies have reported that features do not bias the motion seen in ambiguous split or quartet motion displays. In contrast, features strongly influence correspondence in the Ternus display (e.g., Hein & Moore, VSS 2009, VSS 2010), in particular over short distances in cycling displays (Hein & Cavanagh, VSS 2011). We hypothesized that the absence of a feature bias in previous studies was due to the larger displacements inherent in the split and quartet motion stimuli and the shorter presentation time of the displays. To test this, we compared the influence of distance and presentation time on feature biases in split motion and the Ternus display. We varied the horizontal offset between consecutive sets of discs as well as the number of presentation cycles and biased the percept toward one motion percept or the other by matching surface polarity and line orientation. Surprisingly, we found strong feature effects in both cycling displays, but this effect decreased with distance only in the Ternus display, whereas it remained robust at all distances in the split motion display. Furthermore, the presentation time of the display strongly affected the feature bias in split motion but not in the Ternus display. We speculate that in split motion the feature bias takes time to develop so that they become apparent in our repeating display whereas the single trials of previous studies did not. In the Ternus display, on the other hand, the feature effect is immediate.

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56.531 **The flash-drag effect and the illusory position shift induced by motion on a different depth plane**

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The motion-induced position shift (MIPS) (DeValois & DeValois, 1991) and the flash-drag effect (FDE) (Whitney & Cavanagh, 2000) are examples of illusory position shifts induced by visual motion information. Previous studies have revealed that several different kinds of motion induce these illusions. However, their selectivity for binocular disparity is largely unknown. The disparity tuning of the MIPS and FDE, or the absence of it, would be indicative of the degree of contribution from processing stages in which depth relationship is not made explicit. In the MIPS experiment, a sinusoid with a disparity was windowed by a static Gaussian envelope with zero disparity. The background was filled with static random noise. Subjects correctly reported whether the grating was in front or behind. Two such Gabor patches with the same disparity were presented 7 deg above and below the fixation point and moved horizontally in opposing directions. We determined the position of subjective alignment as the magnitude of the MIPS. We found that the MIPS occurred even when the grating had a different disparity than the envelope's. From the results of the current and previous studies on the MIPS, we argue that the MIPS involves several distinct visual processing stages. In the FDE experiment, two random-dot patterns having the same disparity were presented in upper and lower portions of the visual field and moved horizontally in opposing directions. Two Gaussian blobs with zero disparity were flashed outside these moving random-dot patterns. The FDE, quantified as the position of subjective alignment, also occurred with crossed disparities, but there was a tendency that the magnitude of the FDE reduced with uncrossed disparities. From these results, we will propose possible neural mechanisms that underlie these illusions. In particular, we will discuss the degree of functional independence between motion-based computation of position and disparity-based depth ordering.

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56.532 The flash-drag effect is observed somewhat before, but never after, the display period of a moving stimulus

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The location of a stationary flashed object appears shifted in the direction of nearby motion (flash drag effect; FDE). Previous studies have reported the FDE with a temporal tuning as broad as hundreds of milliseconds for various stimulus configurations (Durant & Johnston, 2004; Shim & Cavanagh, 2005; Fukiage, Whitney & Murakami, 2011). Contrary to this notion, we demonstrate that the FDE has a relatively narrow temporal tuning. We systematically varied the stimulus onset asynchrony (SOA) between the flash and the moving stimulus. If the perceived position of the flash is affected by the presence of motion within a broad temporal window located before and after the flash onset time, the FDE should be broadly observed well before and well after the period within which the moving stimulus was actually displayed. We presented a vertically drifting sinusoidal grating for 500 ms, and briefly flashed a horizontal bar next to it at various SOAs. We asked observers to judge the vertical offset between the flash and the central fixation cross in two-alternative forced choice, and determined the physical offset required to establish the subjective alignment as the magnitude of the FDE at each SOA. We found that the FDE began to occur approximately 100 ms before the onset of the moving stimulus and sharply increased with increasing SOA, and that the FDE started to decrease approximately 100 ms before the disappearance of the moving stimulus and quickly vanished thereafter. Our results suggest that under a certain condition, the position of the flash is calculated in reference to visual events that occur only within a time window as narrow as 100 ms. To reconcile apparent controversy between these results and early views, multiple levels of position processing and differences in task strategy are discussed in relation to object localization from impoverished visual inputs.

Acknowledgement: This study was supported by JSPS Funding Program for Next Generation World-Leading Researchers (LZ004).

56.533 A paradoxical peripheral plaid motion phenomenon

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The motion direction of a moving sinewave grating is ambiguous. The motion of a plaid, consisting of any two arbitrary translating sinewave gratings is not ambiguous; there is always rigid direction that corresponds to a translation of a snapshot of the plaid. The rigid direction can be determined by the "intersection of constraints" (Adelson & Movshon, Nature1982). In Type 1 plaids, the rigid direction and the vector average direction (of the component sinewaves) are similar; in Type 2 plaids, they differ strongly (Ferrera & Wilson, VisRes1987). In foveal viewing, at high temporal frequencies (12.5+25 Hz) that favor first-order motion perception, the Type 2 plaids investigated here are perceived to move in a vector average direction. At low temporal frequencies, especially with components of equal high contrasts that favor third-order motion perception (feature tracking), the same Type 2 plaids are perceived in the rigid direction (e.g., Liu & Sperling, JOV2008). In the periphery, where acuity is reduced, typically motion perception is biased towards a lower order motion perception system relative to the fovea (Lu & Sperling, P&P1999). In accord with this tendency, 1.5+3 Hz Type 2 plaids that foveally are perceived in the rigid direction (3rd-order), are perceived in the vector average direction (first-order) when viewed 8 deg peripherally. Paradoxically, the same high-contrast (but not low contrast) Type 2 plaids (with 12.5+25 Hz components) that are perceived in a vector average direction foveally, are perceived in the rigid direction peripherally. The computation of perceived motion in the rigid direction at such high temporal frequencies in the periphery when it is not perceived in the fovea is unexplained.

Acknowledgement: NIH

56.534 Wriggling Motion Trajectory Illusion

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Motion perception is one of the most fundamental aspects of visual perception and, as a result, the mechanisms underlying it have long been of interest. In the studies of motion perception, when moving dots are used as stimuli, their trajectories are, in most cases, set to be straight. In such cases, it is therefore logical to assume that they will be perceived as moving in straight lines. While the assumption seems to be valid in most cases, here we report a novel and robust visual illusion on motion trajectory, with which random dots moving in straight trajectories perceived wriggling. The illusion is observed when hundreds of dots move in straight trajectories and random directions without colliding with each other. In such a condition, the perceived trajectories are wriggling rather than straight. A total of twenty-one observers evaluated this "wriggling motion trajectory illusion" under various conditions. The illusion was most pronounced when there were a large number of dots moving at high speeds (Experiment 1). The illusion was independent of both the distance covered (Experiment 2) and the observer's eye movements (Experiment 3). What causes the wriggling motion trajectory illusion? If hundreds of dots are randomly placed and all are moving in random directions along straight trajectories, it is very likely that many of them will collide somewhere along their paths. However, our stimuli do not contain any collision at all, and the observers did not see the collisions they expected. When the expectation is betrayed, one of the natural interpretations would be that the dots are avoiding each other by changing their paths. Such cognitive reasoning may explain the wriggling motion trajectory illusion. We propose that this "wriggling motion trajectory illusion" illustrates of how perception of motion can be modulated by high-level cognitive processing.

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56.535 The Looking Glass Motion Effect

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"Project LITE: Light Inquiry Through Experiments" is developing software, as well as two-dimensional images and three-dimensional constructible demonstrations of a wide variety of visual perception phenomena. All of these can be seen at http://lite.bu.edu. Most recently, fully vectorized images have been created of stimuli that are particularly effective when presented on large scales (of order one meter on a side or larger) and at high resolution - as is achievable with readily available poster printers. Among these is an image that appears to be new to the vision science community and that produces a particularly striking visual effect. It is patterned after a screen print that was created by the British artist Peter Sedgley in 1966. His suite of 9 prints - each about 0.5 meters on a side - included one ("Looking Glass No. 3") that consists of a uniform red background with an overlying blue circle with fuzzy edges. Using Adobe Illustrator, vectorized versions of this image have been constructed, as well as versions with sharp edges, and ones with no hue, using gray scale only. The red/blue blurred version has the remarkable property of appearing to expand or contract faster than the surroundings as the observer approaches or recedes from it. In this presentation, this effect will be shown and compared with some other subjective motion phenomena: the Ouchi illusion; Leviant's traffic illusion; the Pinna circles rotation effect; and Helmholtz's fluttering hearts. This "Looking Glass" effect, unlike the Ouchi, Leviant and Pinna effects, gains strength with the inclusion of color. The possible roles played by chromatic aberration and other purely geometrical and physical optics contributions to the effect will be analyzed, as well as factors arising further along in the visual system. All of the vectorized PDFs were created in collaboration with Boston University undergraduate Rebecca Puno.

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Eye movements: Saccadic mechanisms

Tuesday, May 15, 2:45 - 6:30 pm

Poster Session, Vista Ballroom

56.539 Finding the target as a reinforcer of saccadic amplitude variability in a visual search task.

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Purpose We recently showed that part of saccadic amplitude variability may be controlled by operant learning (Paeye & Madelain, 2011). Saccadic amplitude distributions were reinforced with a tone depending on amplitude variability criteria. In the present study we designed a new paradigm involving a visual search task to test whether finding a target among distractors could also be effective to reinforce various saccadic amplitude variability levels: the target was visible only if the saccadic amplitude variability reached a specific criterion. Methods Subjects were instructed to perform a visual search task. At the beginning of each trial 24 distractors (0.3 deg circles with a dash tilted to the left) were displayed. We used a gaze-contingent criterion to display the target (a 0.3 deg circle with a dash tilted to the right) at the item location that was looked at. In a first experimental condition the target appeared when the current saccadic amplitude was rare (to increase amplitude variability). In a second experimental condition the target was displayed when the current saccadic amplitude was frequent (to decrease amplitude variability). In a control group target appearance was independent of saccadic amplitudes. Results U-value (measuring distribution uncertainty) increased from a baseline of 0.57 on average to 0.86 at the end of the first experimental condition and then returned to 0.51 after changing the reinforcement criteria. In the control group averaged U-value first decreased (from 0.56 to 0.49) and then remained at a low level (0.52). These results were confirmed in a second experiment. Furthermore we found that learning transferred to regular visual search trials (in which the target was displayed independently of subjects behavior). Conclusion Seeing the target is a consequence controlling saccadic properties. Moreover these results confirm that an operant learning process can guide saccadic amplitude variability.

56.540 Internal Noise Mechanisms of Intra-Saccadic Suppression

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Despite the fast and frequent eye movements that we make – and the resulting, self-induced motion that our eyes receive – our perception of the world remains stable. A decrease in visual sensitivity measured just before and during saccades – termed saccadic suppression – is thought to underlie this perceptual phenomenon. Our goal was to quantify the behavioral phenomenon of saccadic suppression using a formal signal detection model and use this to infer neural mechanisms of saccadic suppression. We employed the Perceptual Template Model (PTM) that relates visual detection to three distinct internal processing mechanisms. The first increases uncertainty about the stimulus; the second adds stimulus-dependent noise to the system; the third adds stimulus-independent noise to the system. We measured contrast thresholds for horizontal gratings flashed for one frame (8 ms) during fixation and during saccades, allowing us to quantify intra-saccadic suppression. We varied the amount of noise in the stimulus. The resulting threshold-versus-noise (TVN) data were used to fit the PTM, separately for fixation and saccade conditions. A comparison of the parameters in the two models allowed us to determine which mechanisms were necessary to account for intra-saccadic suppression. We found that intra-saccadic suppression decreased as external noise increased for low levels of external noise – consistent with a gain reduction mechanism. However, at high external noise levels, suppression remained constant – consistent with stimulus-dependent noise injection. It has previously been shown that saccadic suppression for stimuli presented just before the saccade can be described by a reduction in gain only (Watson & Krekelberg, J Neurosci 2011). Our current results suggest that this mechanism also applies for stimuli presented during a saccade, but that in addition, a source of multiplicative noise reduces the visibility of intra-saccadic stimuli. This quantification serves as a constraint on putative neural mechanisms of saccadic suppression.

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56.541 The attribution of non-foveal saccade endpoints to internal or external causes in saccadic adaptation

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When observers make a saccade to a visual target, the endpoint is often non-foveal. How does the observer know that the non-foveal endpoint is due to oculomotor noise and not to real-object movement? The visual system needs to attribute discrepancies between fovea and target to an internal source (oculomotor noise) or an external source (real-world movement). Previous studies suggest that the visual system knows saccade amplitude (via, e.g., an extraretinal signal), and can thus predict non-foveal endpoints and discriminate between predicted and non-predicted discrepancies (which should then be attributed to the real world). However, previous studies have also shown that non-predicted discrepancies (such as those introduced by surreptitiously stepping the target back during saccade execution) can be attributed to an internal source rather than an external source provided the discrepancy is not too large. Systematic non-predicted internal discrepancies cause the saccadic system to adapt its amplitude to eliminate future errors. We examined how the characteristics of these non-predicted errors influence saccadic adaptation. We had 3 hypotheses: (1) If the saccadic system predicts large and variable discrepancies, then small non-predicted discrepancies are more likely to be attributed to an internal source and to cause adaptation. Therefore, saccades of large amplitude should adapt more than saccades of small amplitude; (2) If non-predicted discrepancies are inconsistent, then they should more likely be attributed to an external source. Therefore, the more consistent the target step across a session, the more adaptation there should be; (3) If the non-predicted discrepancies are too large, they should be attributed to the outside world. Thus, the smaller the average back-step, the less adaptation there should be. The results support these three hypotheses, suggesting that the saccadic system does indeed attribute non-predicted errors to an internal or external source based on the reliability of each source.

56.542 Saccadic adaptation induced by perceptual goal

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Purpose. When a target is surreptitiously displaced forward or backward during a saccade the saccadic amplitude progressively changes. This saccadic adaptation is often viewed as being driven by the mismatch between a predicted and an actual post-saccadic visual position error. However, we recently demonstrated that saccadic adaptation may be induced by reinforcement learning in the absence of a visual position error (Madelain et al, J.Neurophysiology, 2011-106) suggesting that normal saccade adaptation might involve general learning mechanisms rather than only specialized motor calibration mechanisms. We now ask whether changes in saccade amplitude may be induced by the ability to perform a visual discrimination task. We designed a gaze contingent paradigm in which the difficulty of a post-saccadic visual discrimination task depends on the saccadic amplitude. Methods. Subjects were instructed to make a saccade to a peripheral mask stimulus. Immediately after completion of the saccade, a target briefly (20ms) replaced the mask at the saccade goal location. Subjects were required to perform a four-alternative forced-choice discrimination about target identity. In a first condition the luminance of the discrimination stimulus was either high (50% of the trials, discrimination performance well above chance) or low (50% of the trials, discrimination performance close to chance). In a second condition, the discrimination stimulus luminance depended on the saccade gain: if the gain of the current saccade was lower than the median gain, luminance was high; if the saccadic gain was higher than the median gain, luminance was low. Importantly, the saccade target position was unchanged across trials. Results. Saccadic amplitude was reduced by 7.06% on average. In some subjects the amount of gain reduction was higher than 15%. Conclusions. Importantly, these changes in amplitude increased the post-saccadic position error. These results demonstrate that saccadic gain may be affected by the ability to perform a discrimination task.

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56.543 Saccadic Adaptation with an Adapted Visual Error

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To enable the visual system to accurately gather information about the environment in spite of appearing changes in the oculomotor plant saccadic eye movements are continuously adjusted by the brain. If the saccadic target is systematically shifted inward or outward during the saccade for a few tens of trials, the amplitude becomes shorter or longer, respectively. The error signal that mainly drives the saccadic adaptation is the distance of the expected target position to the actual target position after the saccade with respect to the fovea. An open question is the nature of the adaptation process. One possibility is that the motor command which drives the saccade to the presented target is adjusted. The other possibility is a changed perception of the target location. In our study subjects performed rightward saccades of 12 deg amplitude and we presented a constant error of 3 deg to the left of the eye's landing position at the end of each adaptation trial. Beforehand, leftward saccades of 3 deg amplitude, i.e. of the same size as the induced visual error, had been adapted in the same session. If saccadic adaptation is achieved via motor adjustment, there should be no effect of the adaptation of the small saccade on the adaptation course of the large saccade. On the other hand if the adaptation of the small saccade is achieved due to a visual remapping of the target, the change of perceived target location should have a modifying influence on the adaptation of the large saccade. We found a clear effect of the adaptation state of the small saccade on the adaptation course of the large saccade. The results suggest that the saccade amplitude is adapted via an adjustment of target position.

56.544 Saccadic error information from second order motion

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Saccadic adaptation is a regulatory mechanism controlling the amplitude of saccades. It is driven by post-saccadic information about the error made by the saccade. In a typical adaptation paradigm, a static displacement of the visual target during the perceptual inhibition period of the saccade serves as inducer of the post-saccadic error. The post-saccadic error is then the difference between the landing position and the target position. Here we present evidence that saccadic error information can be calculated without the actual existence of a luminance or color defined target. In our study saccades were adapted by a second order motion stimulus. Subjects made saccades over a static noise pattern background. The fixation location and the saccade target position were successively indicated by a red frame (2 by 2 deg). When the subject made the saccade the target frame was extinguished. Thus, after the saccade only the background pattern was visible. 100 ms after saccade offset, clearly separating post-saccadic motion information from the saccade, a cutout of the background noise pattern of the target frame moved with a high velocity of 50 deg/sec either in or against the direction of the saccade (in separate conditions) thus producing second order motion. In a standard comparison of unadapted and adapted trials saccadic amplitude modifications were found. We therefore present evidence that visual motion information is also used to calculate saccadic errors.

56.545 Electrophysiological evidence for feature remapping in macaque MST

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Prior to a saccade, some neurons shift their receptive fields (RFs) to the location that the RF will be in after the saccade (the future field, FF). Current debate focuses on the question whether information about the content of the visual scene in the FF is transferred (feature remapping), or that the transfer is limited to information on the location of salient regions in the visual field (salience remapping). We recorded from neurons in the medial superior temporal (MST) area of one macaque while he was making saccades between two dots. Two patches with independent random motion sequences were present on the screen. One was in the receptive field, the other in a location that would be in the RF after the saccade, but on the periphery, or outside the RF before the saccade (FF). We used a general linear modeling approach to determine the direction tuning in both the receptive and the future field and compare the tuning properties during steady fixation with those obtained pre-saccadically. We uncovered systematic effects of impending saccades on the direction tuning dynamics. Pre-saccadic tuning was often weaker than fixation tuning in the receptive field; this could be related to the behavioral phenomenon of saccadic suppression. Most interestingly we found pre-saccadic direction tuning in locations that were untuned during fixation (i.e. in the FF) as well as a more general pre-saccadic increase in tuning in the periphery of the RF. To our knowledge this is the first electrophysiological evidence that remapped responses are tuned, suggesting that remapping not only transfers salience, but also feature information. This transfer of low-level visual information just prior to a saccade gives the neuron a head start in processing the information in its future field, which could subserve the construction of perceptual stability.

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56.546 Saccadic motor priority trumps visual salience in a free choice task

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Decision making experiments and models have concentrated heavily on perceptual processing. For example, one influential idea is that sensory features of objects are integrated into a single measure of conspicuity, salience, which then determines probabilities of a target being selected by attention or by a saccadic eye movement. Larger objects, or those nearer the fovea, are more salient because of their greater cortical representation, and should be targeted more frequently by saccades than smaller more distant objects. In contrast, we have previously shown that at small eccentricities larger targets elicit saccades of double the reaction time of smaller targets. We argued that target movements that are small relative to target size are given a low response priority by the saccade system since their visual information has changed little. Here, we examine the link between salience and priority by giving human subjects a free choice between two targets of differing priority and/or salience. Specifically, twelve subjects were presented with two simultaneously appearing rings (2, 4 or 8 deg diameter) at different eccentricities (0.5-18deg) to the left and right of central fixation. They were instructed to saccade to the center of either target. We inferred the motor priority for a given target size and eccentricity from reaction times to singly presented targets. Subjects did not simply choose the nearer, more salient target. Instead, they were strongly biased to higher priority targets. Choice probabilities were accurately predicted from priority and reaction times, not from salience. We conclude that in our simple task: 1) Motor priority trumps visual salience; 2) Reaction times and choice are not dissociable; 3) More generally, object size and eccentricity form an automatic, obligatory and fundamental constraint on saccadic decision making.

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56.547 Changing target size affects saccade preparation: motor re-planning or attentional rescaling?

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Saccade programming can be altered by the appearance of a distractor or a countermanding stimulus. Here we look at the effect of changing target size. Saccade latencies are longer when the target steps within the attentional window, than when stepping outside it. We use this difference to measure the time it takes to change the scale of attention, by having a stimulus change size at different times before or after it makes a 2 deg horizontal step. The stimulus was a rotating, segmented ring either 1 or 8 deg in diameter. The number of segments briefly changed at a pseudorandom time during the trial, and subjects reported this number (facilitated by having attention at the appropriate spatial scale) and made a saccade to the target step. In half of the trials, the size of the target was changed. We compared the saccadic latencies of the size-change trials to those of the non-size-change trials. We observed that if the target size-change occurred more than 140 ms before the saccade, the saccade latency reflected the latency appropriate to the new target-size. Inhibition and facilitation of saccades were found, respectively, at times nearer or further from saccade initiation. Interestingly, for large-to-small size-changes we found latencies intermediate between those appropriate for the two target-sizes, consistent with an analog rescaling of the attentional window. Our data place limits on the temporal dynamics of the putative mechanism of attentional rescaling (zoom model). Alternatively, we present a motor re-planning model: A linear decision signal accumulated at either high (small target) or low (large target) rates, with size-changes modeled either as canceling the existing plan, or continuing at the rate appropriate to the new size. This simple scheme was able to reproduce all the key features of the data.

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56.548 **Destination of information transfer across saccades**

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To maintain visual stability across saccades, we should be able to transfer information from the current location to the future location. However, it is not clear whether information is transferred from the current location to the location in the direction opposite the saccade vector (opposite direction location, Rolfs et al., 2011) or from the current location to the location in the direction of the saccade vector (same direction location, Melcher, 2007). To resolve this controversy, we investigated the destination of information transfer during saccades using an object substitution masking paradigm. We first presented a cue to indicate the direction and the location of eye movements (either left or right). Participants had to move their eyes to the cued location, as soon as they heard the sound cue to initiate their eye movements. During saccade, four Landolt Cs were presented for 110 ms and one of them was simultaneously masked with 4 neighboring dots. The Landolt Cs and the four-dot mask disappeared after 110 ms, but the mask could immediately reappear in a different location depending on the following three conditions. In the opposite condition, the mask appeared in the location in the direction opposite the saccade vector. In the same condition, the mask appeared in the location in the direction of the saccade vector. In the control condition, the mask did not reappear. The mask indicated a task-relevant Landolt C (target). Participants' task was to report the orientation of the target. When the mask was reappeared 150~0 ms prior to saccadic onset, orientation discrimination performance in the opposite condition was significantly lower than that in the same or the control condition. These results suggest that during saccades information transfer from the current location to the location in the direction opposite the saccade vector, as suggested by Rolfs et al (2011).

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56.549 **Parallel extraction of information for foveal analysis and peripheral selection of where to look next**

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In natural vision the cycle of fixations and gaze shifts demands analysis of visual information at the currently fixated region for object recognition and identification, but also of the periphery to select the target for the next gaze shift. We asked how time during a fixation is allocated to the foveal discrimination and peripheral selection tasks, and how this allocation depends on the difficulty of foveal discrimination. Observers performed a visual comparison task in a limited period of time. A Gabor patch at fixation fluctuated in contrast and orientation. The mean orientation was offset from vertical in either the clockwise or anti-clockwise direction. Three peripheral patterns also fluctuated in contrast and orientation. One of the peripheral patterns had a higher mean contrast. Observers judged whether the target orientation was the same or different from the patch at initial fixation. The difficulty of the orientation discrimination forced observers to generate a saccade to the target in order to accomplish the comparative judgement. The foveal discrimination and peripheral selection tasks were defined by different visual dimensions. We analysed the noise in both dimensions to identify the temporal epochs during which the information for both tasks was extracted. Orientation information at the fovea was extracted throughout the entire fixation period, right up to saccade initiation. The integration epoch for peripheral selection was shorter and overlapped with the foveal discrimination window. Variation in the difficulty of foveal discrimination did not affect the duration of the integration window. Foveal discrimination and peripheral selection occur in parallel during fixation, with relatively little time spent on analysing peripheral information for saccade target selection. Fixation duration and the duration of the integration window are not under online direct control by the currently experienced processing difficulty.

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56.550 **The dynamic representation of eye position in primary visual cortex.**

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Visual input would be of little use if not accompanied by knowledge of eye position; indeed, it is the combination of these signals that allows the brain to localise and interact with objects meaningfully. Eye-position signals have been observed throughout visual cortex – including the primary visual area (V1) – but little is known about how well such signals represent the eye during fixation and across eye movements. We examined the static and dynamic representation of eye-position in parafoveal V1 of an alert macaque by recording extracellular activity as the animal performed sequences of fixations, saccades, and smooth-pursuit eye movements. To probe population codes for eye position, we recorded from several neurons simultaneously using a chronically implanted multielectrode array. Throughout the task, neurons were stimulated by a flickering binary noise stimulus (75Hz). Consistent with previous reports, we found that many neurons showed substantial and systematic modulations of visually-evoked activity by the position of the eyes in the orbit (i.e. 'gain fields'). We used our knowledge of these tuning functions to decode the eye position from the neural data on a trial-by-trial basis, thereby allowing an assessment of the reliability of eye-position representation. We found that the position of the eyes could be predicted to within a few degrees of visual angle, even using as few as two V1 neurons. We also found that the representation of eye position was updated rapidly after the offset of saccades (within 50-100ms). These findings point to a highly reliable and nimble representation of eye position in primary visual cortex that could support fluid and accurate visuomotor behaviour during normal exploratory vision.

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56.551 **Eye position distribution depends on head orientation**

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((Purpose)) Because our visual field is limited, we need to move our head and body to obtain visual information from wide areas. Although the cooperation between eye and head movements has been reported, there is only limited knowledge of how to move cooperatively. The purpose of this study is to investigate the relationship between eye movements and head orientation while searching for a target in a 360° visual display. ((Experiment))We measured participants' eye movements, head directions, and chest directions while they were searching for a target. Targets were presented on a 360° visual display; six displays surrounding the participant. The task was to search for a letter "T" (target) among 47 "L" shaped symbols (distractors) distributed over the six displays. The participant naturally moved his head, eyes, and body to search for the target and then pressed a button when he found the target. In order to explore the relationship between eye position and head orientation, we analyzed the distribution of eye position as a function of the head orientation relative to the chest direction. ((Results))The results showed clear correlation between eye position and head orientation. When the head pointed to the left or right (relative to the chest), the peak distribution of eye position was also to the left or right (relative to the head). The results also showed that when the head is centered (±5° to the chest), the eye position is also centered in the head. ((Discussion)) The distribution function of eye position is clearly related to head orientation. This finding suggests that gaze locations can be predicted by measuring head movements if we have additional information of visual scenes such as their saliency map.

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56.552 **Motion correspondence based on the perisaccadically compressed space**

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When multiple elements are present in an apparent-motion display, the visual system must solve a motion correspondence problem. The proximity between matching elements is a factor determining correspondence. It has been believed that the proximity computation uses distances in retinal coordinates, but we recently revealed that it also takes into account distances in environmental coordinates during smooth pursuit eye movement (Terao et al, 2008, SfN). This suggests that the processing stage is later than the integration of retinal inputs with extra-retinal signals of smooth pursuit eye movement. It remains unclear whether proximity computation is also modulated by extra-retinal signals of saccade. We examined whether the

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perceptual solution in a motion-quartet stimulus was affected by perisaccadic space compression. The motion quartet yields bistable apparent motion in either a horizontal or vertical direction. Perisaccadic space compression just before a saccade onset involves mislocalization of briefly flashed stimuli toward the position of the saccade target (Ross, Morrone & Burr, 1997), and the illusion strength increases with saccade amplitude (Lavergne et al, 2010). -100 ms to 0 ms before the onset of each horizontal saccade, two diagonally opposing pairs of disks (inter-disk distance 6 deg) centered at the saccade target were flashed successively with the inter-stimulus interval of 50 ms. Because compression occurred only in the horizontal direction, horizontal proximity became subjectively closer than the vertical proximity, even though the actual inter-disk distance was identical. If subjective proximity determines correspondence, the probability of perceiving horizontal motion would increase, and this was indeed what we found. We also found that the effect became weaker with decreasing saccade amplitude, which is also consistent with the hypothesis that perisaccadic space compression affects motion correspondence. Our findings suggest that proximity computation for motion correspondence is based on the space affected by extra-retinal signals.

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56.553 **Priming of popout is preserved across eye movements**

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In visual search, faster response times occur when the target repeats its location or color across trials (Maljkovic & Nakayama, 1996, Percept Psychophys). This "priming of pop-out" (PoP) phenomenon occurs spontaneously in the absence of eye movements, but does it persist across eye movements? With every saccade, the retinotopic (eye-centered) coordinates of objects change, and spatial representations must be updated to accommodate spatiotopic (world-centered) locations. However, this updating process takes time and may depend on the spatiotopic location being task-relevant (Golomb et al, 2008 J Neurosci). PoP reflects regularities in our environment and would be most useful in spatiotopic coordinates, but it is thought to be an implicit process. Does PoP spontaneously update to spatiotopic coordinates after an eye movement? Participants fixated on a cross while six colored diamonds appeared in the periphery. They then reported which side of the uniquely colored diamond (the target) was cut off. On half of the trials the fixation cross stayed in the same location as the previous trial; on the other half fixation moved to a new location. When fixation moved, trials were compared in which the target appeared in the same spatiotopic, same retinotopic, or completely different location as the previous trial. We also compared trials in which target and/or distractor colors switched or repeated. Results showed that PoP for both location and color still occurred across intervening eye movements: participants were significantly faster if the target appeared at the same spatiotopic location compared to when it appeared at a different location. Faster RTs also occurred when either the previous target or distractor color repeated, regardless of whether fixation changed. These results demonstrate that PoP for both color and location survives an eye movement, and further, the PoP phenomenon may result from a higher-order process that functions in non-retinotopic, behaviorally relevant coordinates.

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56.554 **The role of the frontal eye fields in oculomotor competition: image-guided TMS enhances contralateral target selection**

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In order to execute a correct eye movement to a target in a search display, a saccade program towards the target element must be activated while saccade programs towards distracting elements must be inhibited. The aim of the present study was to elucidate the role of the frontal eye field (FEF) in oculomotor competition. fMRI guided transcranial magnetic stimulation (TMS) was administered over the left FEF, the right FEF or the vertex (control site) at three time intervals after target presentation, while subjects performed an oculomotor capture task. When TMS was applied over the FEF contralateral to the visual field where the target was presented, less interference was observed from an ipsilateral distractor compared to stimulation of the FEF ipsilateral to the target's visual field or stimulation of the vertex. Furthermore, TMS over the FEF contralateral to the visual field of the target decreased saccade latencies to the target, whereas contralateral distractor-oriented saccades were not affected. These findings elucidate the role of the FEF in oculomotor competition by showing that TMS over the FEF does not enhance the selection of a contralateral stimulus-directed saccade per se, but specifically enhances the activation of a contralateral saccade towards a pre-instructed target.

56.555 **Distributed spatial coding accounts for saccades made to singleton targets as well as eye movements during reading**

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It is generally assumed that the metrics of saccadic eye movements reflect the distributed nature of spatial coding in the Superior Colliculus (SC). Neurons in the sensory and motor maps of the SC have large and overlapping receptive / movement fields, and it is the simultaneous activity of populations of neurons coding for neighboring locations in space which determines where the eyes move. This drives the eyes relatively precisely to a singleton target, but as a counterpart, biases the eyes to land at an intermediate location between two simultaneously-displayed visual stimuli. Here, I will argue that distributed coding, as a general property of the saccadic system, accounts not only for saccades to singleton target stimuli, but also for eye movements in reading. First, I will report new data showing that the eyes move to different locations in words depending on the visual context, thus confirming that saccade averaging generalizes to reading. Second, I will provide converging evidence from several of our studies using words as well as singleton stimuli, that saccade averaging operates over a limited area. As we have previously shown, this area is best defined in millimeters of collicular surface, thus when the non-homogenous afferent/efferent mapping property of the SC is taken into account; I will show here that it is nearly of the same extent irrespective of the stimulus material. Third, I will report that the greater representation of foveal compared to peripheral input in the collicular map shapes the distribution of landing sites in the vicinity of an isolated, singleton target, but also influences where the eyes move in more complex stimulus configurations. I will then delineate the basic principles of a novel theory of saccade generation in reading, discussing the possibility that distributed coding might be relayed by lateral interactions within the collicular map.

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56.556 **The prior-antisaccade effect: Decoupling stimulus and response inhibits the planning and control of subsequent prosaccades**

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The classic AABB task-switching paradigm has demonstrated that a prosaccade completed after an antisaccade elicits longer response latencies, reduced online trajectory amendments and less accurate endpoints than the second of two consecutively completed prosaccades (i.e., the prior-antisaccade effect; Weiler and Heath, 2012: Exp Brain Res). In the current investigation, we sought to determine whether the prior-antisaccade effect arises from the top-down requirements of the recently completed mirror-symmetrical response (i.e., response suppression and vector inversion) or is related to an explicit task ordering effect. To accomplish that objective, participants completed pro- and antisaccades to a briefly presented target (50 ms) in left and right visual space in two saccade task-switching blocks. In one block the AABB task-switching paradigm was employed wherein pro- and antisaccades were alternated on every second trial. In the other block, pro- and antisaccades were pseudo-randomly interleaved on a trial-by-trial basis thus preventing participants from predicting the nature of the upcoming task. Importantly, both blocks were equated for response-repetition (i.e., pro- or antisaccade followed by the same task) and response-switch (i.e., pro- or antisaccade followed by the opposite task) trials. To index online control, we computed the proportion of variance explained by the spatial location of the eye at normalized increments of movement time relative to the eye's ultimate endpoint. Results demonstrated that response-switch prosaccade trials yielded longer latencies and fewer online corrections compared to their response-repetition counterparts. Notably, this

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pattern was not modulated across the AABB and pseudo-randomized trial blocks. Thus, a priori knowledge related to the nature of an upcoming task (i.e., pro- or antisaccade) does not account for the prior-antisaccade effect. Rather, we propose that the top-down requirements of the antisaccade result in a systematic inhibition of the oculomotor networks that support the planning and control of subsequent prosaccades.

Acknowledgement: NSERC, Ontario Graduate Scholarship

56.557 **Pupil dilation evoked by a salient auditory stimulus facilitates saccade reaction times to a visual stimulus.**

Chin-An Wang[1](josh.wang@queensu.ca), Susan Boehnke[1], Douglas Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University, Canada

The orienting reflex is initiated by a salient stimulus to prepare the body for quick, appropriate action. It involves a rapid shift of the eyes, attention, and other physiological responses, including pupil dynamics. The superior colliculus (SC) is a critical structure in the brain network that coordinates orienting behaviors, and we have previously shown that microstimulation of the SC in monkeys not only shifts in gaze and attention but also evokes pupil dilation. Although pupil dilation is characterized as an important component of the orienting reflex, its functional role remains poorly understood. It has been hypothesized to increase visual sensitivity. We first used a salient infrequent auditory stimulus to evoke pupil dilation. An auditory tone at zero azimuth (1000 Hz, 50 ms) was presented on only 20% of trials while monkeys fixated a central point. The pupils dilated transiently after the auditory stimulus presentation with dilation onset about 200 ms and dilation peak about 500 ms after stimulus onset, confirming that pupil dilation was triggered by auditory stimuli. Then, we presented a visual saccadic target after the auditory cue to examine the effect of evoked pupil dilation on saccadic reaction times. Critically, we manipulated the cue-target onset asynchrony (CTOA: 100-850 ms) according to the time course of evoked pupil dilation, so the size of the pupil varied at different times of target presentation. Pupils dilated maximally when the CTOA was 400 ms, the condition for which the evoked pupil size was maximal during target presentation. Moreover, saccade reaction times were negatively correlated with actual pupil size (faster reaction times occurred with a larger pupil), suggesting that pupil size influences ongoing target processing. Together, these results suggest that pupil dynamics are associated with saliency, and that stimulus-evoked pupil dilation may facilitate target processing for action.

Tuesday PM

Wednesday Morning Talks

Eye movements: Perception and cognition

Wednesday, May 16, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 1-3

Moderator: Alejandro Lleras

61.11, *8:00 am*

Visual perception at the time of successive saccades

Eckart Zimmermann[1,2](eckart@in.cnr.it), M Concetta Morrone[2], David C Burr[1,3]; [1]Psychology Department, University of Florence, Italy , [2]Department of Physiological Sciences, University of Pisa, Italy , [3]Neuroscience Institute, National Research Council, Pisa, Italy

Saccadic eye movements profoundly influence the perception of space: stimuli presented briefly around saccadic onset are perceived compressed towards the saccadic target. We studied perisaccadic mislocalization with a double-step saccade paradigm, an important technique in eye-movement research where the second saccade needs to be planned before the first has been executed, and must therefore take into account the displacement caused by the first. In our study the saccades were "memory-guided", with both saccadic targets extinguished before commencing the sequence. We measured perisaccadic localization of a small probe dot briefly flashed at various times during the sequence. At onset of the first saccade, probe dots were mislocalized towards the first and also the second saccade target. However, on onset of the second saccade, there was very little mislocalization. We reasoned that the lack of mislocalization could reflect failure to encode the location of the second saccadic target in an appropriate coordinate space (that takes into account the motion of the first saccade). Perhaps this encoding takes time? To test this idea, we increased the viewing duration of the saccade targets (before commencing the saccade sequence), and observed mislocalization at onset of both the first and second saccade. Our data suggest that construction of the spatiotopic representation requires at least 200 ms, a notion reinforced by a series of experiments on saccadic displacement of motion. We conclude that perisaccadic mislocalization towards the saccade target occurs only after neural map has been constructed in suitable coordinates, and the construction of this map requires time.

Acknowledgement: Stanib

61.12, *8:15 am*

Eye movements play an active role when visuospatial information is recalled from memory

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Whilst it has been established that spontaneous eye movements occur with visual imagery and that they are comparable with those from an original scene inspection (e.g., Brandt & Stark, 1997; Johansson, Holsanova, & Holmqvist, 2006), the exact purpose of these eye movements has been a hot topic of debate (cf., Ferreira et al., 2008; Richardson et al., 2009). Do they have an active and functional role in memory retrieval or are they merely an epiphenomenon? In a recent study we reported that when eye movements were prohibited for participants who orally described pictures from memory, their recollections became altered and impaired (Johansson, Holsanova, Dewhurst, & Holmqvist, (in press). Journal of Experimental Psychology: Human Perception and Performance). The current study was designed as a follow-up, aiming to uncover exactly how imposing different eye movements on participants affects memory retrieval processes. Eye movements were recorded from participants who recalled properties and spatial arrangements of sets of objects under four different manipulations: (1) free viewing on a blank screen; (2) gazing at a fixation cross; (3) looking at an area which was matched with the original locations of the objects to be recalled; (4) looking at an area which did not match the original locations of the objects to be recalled. By restricting eye movements in different ways during recall, we demonstrate the sensitivity of retrieval performance to specific eye movement manipulations. Results provide evidence that eye movements do have an active and supportive role when visuospatial information is recalled by highlighting the circumstances under which a visual memory is hampered. Additionally, findings suggest that the influence of "eye movements to nothing" is primarily related to the processing and retrieval of spatial information.

61.13, *8:30 am*

Action Affordance Influences on Eye-Movements and Object Prioritisation in Real World Scenes.

Konstantinos Tsagkaridis[1](ktsagkar_psy@yahoo.gr); [1]Moss Rehabilitation Research Institute

Abstract Recent developments in technology have provided researchers with the opportunity to explore the interactions between motor and perceptual systems in the brain. A series of experiments have demonstrated effects of action affordances on object perception. Their combined results seem to imply pre-attentive effects on object perception independent of the person's intention to act on an object (Riddoch, Humphreys, Edwards, Baker & Wilson, 2002; Tipper, Paul & Hayes, 2006; Symes, Ellis & Tucker, 2007). Our experiments took advantage of the phenomenon of object prioritization during unexpected onsets or feature changes of objects, while our participants were viewing real world scenes (Brockmole & Henderson, 2005a). Eye-tracking data were recorded to measure at which point action affordance manipulations would have an effect. By comparing action affordance interference during object onsets against interference during object orientation changes we could differentiate between pre-attentive and post-selection mechanisms. Our results indicate that although there is no evidence of pre-attentive modulation of object prioritization, action affordances do have an effect in post-selection mechanisms, with functionally inconsistent objects attracting attention faster than functionally consistent objects. Also, action affordances affected the encoding of an object in the scene representation during memory guided prioritization, but not during oculomotor capture. Our results therefore support the existence of two separate mechanisms for object prioritization (Brockmole & Henderson, 2005a, 2005b). This finding, in conjunction with our previous research, is consistent with recent evidence that such action affordance influences on visual perception might be based on implicit motion (Riddoch, Bodley Scott & Humphreys, 2010). Moreover, our analyses indicate that the advantage of functionally inconsistent objects to attract attention earlier than functionally consistent ones can be accounted for by the modulation of the viewing time spent on an object violating familiar schemata.

Acknowledgement: IKY (Hellenic State Scholarships Foundation)

61.14, *8:45 am*

Automatic selection of eye tracking variables uncovers similar mechanisms for visual categorization in adults and infants

Samuel Rivera[1](rivera.162@osu.edu), Catherine Best[1,2,3], Hyungwook Yim[1,2,3], Dirk Walther[1,2], Vladimir Sloutsky[1,2,3], Aleix Martinez[1]; [1]ece.osu.edu, [2]psy.ohio-state.edu, [3]cog.ohio-state.edu

Visual categorization and learning of visual categories are fundamental cognitive processes not yet well understood in infants. The main limiting factor for examining these mechanisms is the limited duration of infant cooperation (10-15 minutes), which leaves little room for multiple test trials. With its tight link to visual attention, eye tracking is a promising method for getting access to the mechanisms of category learning. But how should researchers decide which aspects of the rich eye tracking data to focus on? In the past, eye tracking variables were picked by hand, often resulting in biases or sub-optimal exploitation of the eye tracking data. Here we propose an automated method for selecting good eye tracking variables based on their usefulness to discriminate learners from non-learners of visual categories. We presented infants and adults with an unsupervised category learning task and tracked their eye movements. We then extracted an overcomplete set of eye tracking variables, encompassing durations, probabilities, latencies, and the order of fixations and saccadic eye movements. We compared three statistical techniques for identifying those variables among this large set that are useful for discriminating learners form non-learners: ANOVA ranking, Bayes ranking, and L1 regularized logistic regression. We found remarkable agreement between these methods in identifying a small set of features. These features allowed us to discriminate learners from non-learn-

See page 3 for Abstract Numbering System

ers in the adult population with 76% accuracy (chance: 50%), using a linear support vector machine. Moreover, the same eye tracking variables also allow us to classify category learners from non-learners among 6-8 month-old infants with 70% accuracy. This result suggests very similar processes underlying unsupervised category learning in infants and adults.

Acknowledgement: NIH grants R01-EY-020834

61.15, *9:00 am*

The effect of uncertainty and reward on fixation behavior in a driving task

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Most current models of human fixation behavior do not address the complex issue of how fixations are selected in dynamic, interactive natural tasks. Sprague et al (2007) proposed a model that explains task-based fixations as the outcome of arbitration between competing visual tasks. Fixation target selection uses a metric that weights reward estimates for task modules with uncertainty estimates for task relevant visual features. While reward has a known role in gaze allocation, there is little research addressing the role of state uncertainty, particularly in natural tasks. To address this, we manipulated rewards and task uncertainties while subjects drove in a virtual environment. Subjects drove through a virtual city in four conditions, which varied task importance and the presence of uncertainty. Implicit reward was manipulated by instructions that either emphasized driving an exact speed or following another car. Uncertainty was introduced by adding small random variations to the car's speed and was reflected by the car's speedometer. When exact speed was most important, adding uncertainty increased fixation proportion on the speedometer by 6%, and showed a trend to increase fixation durations by 80 ms and reduce inter-fixation intervals by 1s, over the same condition without uncertainty. This pattern was modulated in the following conditions where speedometer fixations were less important. When exact speed was most important with added uncertainty, the proportion of fixations on the speedometer increased by 16%, fixation duration increased by 170ms, and inter-fixation interval reduced by 6s over the follow condition with added uncertainty. These result suggest that when the state of a task-relevant visual variable becomes uncertain, subjects prioritize its gaze allocation, but only when this is a task with high reward. Thus both reward and state uncertainty are important components of gaze control in natural behavior, consistent with predictions from Sprague et al's model.

Acknowledgement: NIH grants RR02983, MH60624, and EY05729

61.16, *9:15 am*

Dopaminergic modulation of saccadic control

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Processing pathways involved in saccadic control have been elaborately described over the last years, however little is known about the dynamic modulation of saccades by specific neurotransmitters. Clinical as well as recent experimental evidence suggests that prefrontal dopamine not only plays an important role in cognitive functions, but also in sensorimotor processes. We were interested in saccadic latency in healthy adults with supposed differences in dopaminergic activation. Catechol-O-methyltransferase (COMT) plays a major role in the regulation of prefrontal dopamine levels. The COMT val158met polymorphism modulates enzyme activity in that met alleles lead to less active dopamine degradation and accordingly to higher dopamine levels. We investigated latency of reflexive saccades in 110 subjects (91 females, age M=23.2, SD=4.9) and determined the individual genotypes (ValVal n=24, ValMet n=54, MetMet n=32). Subjects had to make horizontal saccades to targets presented either in an overlap or a gap condition. In the overlap condition, the fixation stimulus remained present during target presentation, in the gap condition, the fixation stimulus disappeared 200ms before target onset. Introducing a gap has been shown to substantially reduce saccadic latencies by inducing a preparatory process. Analysis of saccade latencies revealed significant differences between genotypes in the overlap condition ($F(2, 109)=10.2$, $p<.001$), but not in the gap condition ($F(2, 109)=0.6$, $p=.573$). In the overlap condition Met allele carriers showed higher latencies than Val homozygotes. We confirmed a significant interaction between genotype and gap condition ($F(2, 107)=8.4$, $p<.001$). The gap condition elicited a greater latency reduction in Met allele carriers. Our results provide evidence of dopaminergic modulation of saccadic control in healthy subjects. We relate our findings to the tonic-phasic dopamine hypothesis proposing that higher prefrontal dopamine levels trigger increased stability and decreased flexibility of subcortical network activation. We suppose that this pattern might be a disadvantage when preparatory processes are minimized.

61.17, *9:30 am*

Where do the eyes go when you think? Away from visually salient information.

Alejandro Lleras[1](Alejandro.Lleras@gmail.com), Simona Buetti[1]; [1]Department of Psychology, University of Illinois

Vision scientists have long considered vision, and visual attention specifically, to function as a sort of survival alarm system: always ready to detect novelty, salience, or changes in the environment to alert us of and orient us towards those changes. In spite of the adaptive face validity of that argument, we argue that this assumption does not hold up to close scrutiny. Here, we asked participants to do a 20-step arithmetic task. Participants initially saw a three digit number at fixation, followed every 3 seconds by an operation (displayed for 500ms), to update their current total. The central area was completely empty for 83% of the total trial duration. Critically, large photographs were presented at one of four possible peripheral locations during the trial. Each picture remained on screen for 3 seconds. A new image would onset approximately 1.8 seconds after the latest operand had disappeared from the screen, which (we confirmed) was sufficient time to complete most operations. The appearance/disappearance of peripheral images were the only visual events occurring at these times (no visual information was present at the center). Results: (1) Participants eyes stayed at the center ~60% of the total trial duration. (2) Participants only spent ~10% of trial time looking at peripheral images. (3) In spite of being substantial visual transients, participants never directed their eyes towards new onsets. If their eyes happened to be near the location of a new picture when it appeared, the eyes quickly moved away from the picture. When we are oriented towards the world, vision may play the role of alarm system; yet, in the many instances when we are inwardly oriented (focused on our thoughts), the eyes do what's right: they work to actively minimize possible distraction from the world, by actively staying away from sources of distraction.

Binocular rivalry and figure/ground competition

Wednesday, May 16, 8:00 - 9:45 am

Talk Session, Royal Palm Ballroom 4-5

Moderator: Jan Brascamp

61.21, *8:00 am*

Perceptual proof that inattention abolishes binocular rivalry

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Abundant psychophysical evidence indicates that attention can influence the fluctuations in perception that characterize binocular rivalry. Here we ask an even more fundamental question: can binocular rivalry even occur without attention? Recent psychophysical1,2 and EEG3 results imply that rivalry ceases altogether when rival stimuli are unattended. We used a novel paradigm to provide perceptual verification of this important conclusion. This involved overcoming an obvious problem: rivalry perception cannot be reported by an observer whose attention is fully allocated elsewhere. Our observers therefore reported perception immediately before withdrawing attention from rivalry and again, a few seconds later, upon returning attention to rivalry. Because an individual's percept durations during rivalry tend to fall within a narrow range (i.e. the duration distribution is tightly peaked rather than uniform), a strong statistical association normally exists between perception at one moment and perception seconds later. This same association is expected between two moments straddling a period of inattention if and only if rivalry continued during that period. In a baseline condition we determined the exact association between perception of a rival stimulus at two moments some time apart. In a second condition we observed that this association was abolished when replacing the stimulus with a blank screen during the period separating the two moments. In the third condition the stimulus remained, but attention was withdrawn. Results from this third condition strongly deviated from the association observed in the first condition. Instead, reports exactly matched those obtained in the second condition where the rivalry conditions were physically removed. Thus, disregarding a stimulus that ordinarily produces binocular rivalry is tantamount to removing it from view. Inattention, in other words, abolishes binocular rivalry. 1. Cavanagh & Holcombe, VSS 2006; 2. He et al, VSS 2007; 3. Zhang et al (2011), Neuron 71(2): 362-9

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61.22, *8:15 am*

Disentangling the influences of different cues on perceptual grouping during binocular rivalry

Sjoerd Stuit[1](S.M.Stuit@uu.nl), Chris Paffen[1], Maarten van der Smagt[1], Frans Verstraten[1]; [1]Division of Experimental Psychology, Helmholtz Institute, Utrecht University

During binocular rivalry, incompatible dichoptic images compete for perceptual awareness. Dichoptic images do not compete for awareness independently when rivalry is instigated at multiple locations of the visual field. This inter-dependence is thought to be the result of perceptual grouping. We use the inter-dependence in perceptual dominance to disentangle the effect of different cues on grouping during rivalry. Specifically, the simultaneous dominance of spatially separated competing images can be based on similarities in their image-content as well as which eye they are presented to. We presented spatially separated rival images such that similar images were either presented to the same or to different eyes. Since rivalry competition can be resolved at multiple stages along the visual processing hierarchy we also tested whether the influence of different cues depends on the type of images used. In two experiments, we used a perceptual tracking paradigm to measure the durations of perceiving either identical versus different orientation (Exp_1) or perceiving parts of a face versus parts of a plaid (Exp_2). For rivaling orientations (Exp_1), we found eye-of-origin to be the strongest cue for grouping. In addition, image-content is also a cue for grouping, as images with identical orientations were perceptually dominant together longer than images with dissimilar orientations, even when they were presented to different eyes. However, in Exp_2, when faces were in binocular competition with plaids, the influence of the cues reversed. That is, in this experiment image-content was the stronger cue for grouping although eye-of-origin still influenced the dominant percept. We are able to directly compare these different contributions that originate at different levels of the visual processing hierarchy. Overall, our results show that eye-of-origin and image-content cues can independently affect grouping during rivalry and that their relative contributions can further be affected by the semantic content of the competing images.

61.23, *8:30 am*

Spatial motion coordinates that determine perceptual dominance in binocular rivalry

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It is known that moving stimuli dominate in binocular rivalry over static stimuli. Recent evidence shows that visual motions can be processed in spatiotopic or object-based as well as retinotopic coordinates. Here we examined relative contribution of these coordinates by independently manipulating motions of grating stimulus, background, and fixation marker. Six observers dichoptically viewed a pair of diagonal gratings with different orientations (45 and 135 deg). The grating for one eye was static while that for the other eye was drifting (6 deg/sec). There was a gray background (6.3 x 9.4 deg) surrounding each stimulus together with a fixation marker presented on the left side of grating stimulus. The observers judged which grating appeared dominant during 2 sec trials. The contrast ratio where dominance balances was obtained by systematically varying contrasts. Eye movements were monitored. It was found that drifting gratings were dominant over static gratings when observers maintained stationary fixation. However, when they tracked the fixation marker that moved together with the drifting grating, the physically drifting but retinotopically static gratings became dominant, indicating that retinal motion by itself is not the determining factor. When the background was moved together with the fixation marker, the gratings drifting in retinotopic and object-based coordinates dominated over physically drifting gratings. Thus, the existence of object-based motion seems the determining factor, but it is not since gratings with both retinotopic and physical motion but with no object-based motion became dominant when background alone was moved. These results, therefore, indicate that retinal motion is not the determinant for the dominance. Subsequent quantitative analyses revealed that the contribution of spatiotopic and object-based motions to the dominance are equal or even larger than retinotopic motion. These results demonstrate a significant involvement of non-retinotopic motion signals in triggering the conscious awareness of visual stimuli.

61.24, *8:45 am*

Binocular suppression occurs in object-centered coordinates

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In binocular rivalry, only one image is perceived consciously when different, incompatible images are presented to the left and right eye, respectively. The other image is suppressed. Binocular suppression is generally assumed to occur within retinotopic coordinates. However, the world is continuously shifting on our retina because of the movements of the eyes and the objects themselves. Therefore, the visual system needs a mechanism to create binocular perceptual stability despite continuous changes in the retinal images. To investigate retinotopic versus object-centered binocular suppression, we combined the Ternus-Pikler paradigm with a binocular selective suppression paradigm. We presented a Ternus-Pikler display (TPD) in which three disks shifted by one position from frame 1 to frame 2. We presented a low-contrast grating in the central disk of the TPD to one eye and a high contrast bull's eye at the same location to the other eye. The bull's eye fully suppressed the percept of the grating. In the second frame, in half of the trials, a grating was presented on the central disk. In the other half, no grating was presented. The orientation of the grating (when presented) was the same as or orthogonal to the orientation of the first grating. No bull's eye was presented in the second frame. Sensitivity to gratings with the previously suppressed orientation was reduced compared to orthogonal gratings, even though the gratings in both frames were presented at different retinotopic locations. These results are evidence for feature suppression in non-retinotopic, object-centered coordinates, giving rise to a new view on binocular rivalry where stimulus-selective, non-retinotopic inhibition is crucial in maintaining perceptual stability.

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61.25, *9:00 am*

Preserved local but disrupted contextual figure-ground influences in a patient with abnormal function of intermediate visual areas

Joseph Brooks[1](joseph.brooks@ucl.ac.uk), Sharon Gilaie-Dotan[1,2], Geraint Rees[1,2], Shlomo Bentin[3], Jon Driver[1,2]; [1]Institute of Cognitive Neuroscience, University College London, [2]Wellcome Trust Centre for Neuroimaging, University College London, [3]Department of Psychology & Center for Neural Computation, Hebrew University of Jerusalem

Visual perception depends not only on local stimulus features but also on their relationship to the surrounding stimulus context. Many known visual figure-ground cues are based on local edge features such as edge convexity, adjacent region brightness, or previous experience. Recently though, contextual influences from remote, non-adjacent edges have also been shown to affect figure-ground organization (Zhang & von der Heydt, 2010; Brooks & Driver, 2010; Peterson & Salvagio, 2008). Intermediate visual areas may play a role in such contextual influences. We tested this by examining a rare case (LG) of developmental visual agnosia. A previous study showed that LG had no evident abnormality of brain structure and functional neuroimaging showed relatively normal V1 function. In contrast, his intermediate visual areas (V2/V3) were deactivated in response to visual stimulation. To determine whether this abnormal pattern of visual cortical function may selectively affect contextual processing, we tested LG on a set of local figure-ground cues as well as contextual figure-ground influences. We showed LG dynamic displays with two bipartite sections. Figure-ground assignment of the dividing edge within one bipartite section was locally-

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biased in one direction by an edge-region grouping cue (Palmer & Brooks, 2008). The dividing edge of the other section was locally-ambiguous with regard to figure-ground assignment. In control participants figure-ground assignment of the locally-ambiguous edge is affected by the locally-biased edge in the context. We found that although LG's figure-ground assignment in the locally-biased section was equivalent to controls, contextual influence on the locally-ambiguous section was significantly reduced. Our results suggest dissociable mechanisms for contextual and local influences on figure-ground assignment. These results suggest that computational and neural models of figure-ground organization should contain dissociable mechanisms for local and contextual influences.

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61.26, *9:15 am*

Binocular rivalry-like neural activities in anesthetized macaque V1

Haoran Xu[1](hrxu@ion.ac.cn), Chao Han[1], Ming Chen[1], Peichao Li[1], Shude Zhu[1], Zijiang He[2], Haidong Lu[1]; [1]Inst. of Neuroscience, Chinese Acad. of Sci., Shanghai, China, [2]Dept. of Psychological and Brain Sci., Univ. of Louisville, Louisville, KY

While the binocular rivalry (BR) stimulus is processed over multiple cortical areas, it is unclear how much the neural activities in area V1 contribute to its perception. To investigate this, we examined whether V1 neural activities when deprived of top-down attention control, alternate like the typical BR perception. Intrinsic signal optical imaging was employed to measure population response from V1 of anesthetized and paralyzed macaque monkeys. The BR stimulus comprised a pair of 45 and 135 deg gratings (diameter: 1.5-3.5 deg, spatial frequency: 2 cpd; speed: 3 deg/sec) in green and red colors. The imaging pattern from each 0.25-second frame over a 60-second stimulation period was evaluated for its similarity to either the left or right eye alone activation pattern, from which we derived the eye-dominance score. Accordingly, by classifying each frame as left or right eye dominance, we are able to reveal a clear alternation of eye dominance over time. We estimated the mean eye dominance duration to be in the range of 2 to 8 seconds. Also revealing is the difference (subtraction) between the classified left and right eye dominance image maps. We found the subtracted map closely matches the ocular dominance column map, confirming the eye-of-origin specificity of the estimated eye dominance status. Finally, these characteristic optical imaging patterns (ocular dominance map) are not observed in a control condition where the monkeys viewed a non-rivaling binocular stimulus (e.g., random dot patterns or plaids). Overall, our findings demonstrate that there exist eye specific neural activities in V1 that alternate during BR stimulation and occur without conscious top-down attention modulation.

61.27, *9:30 am*

Predicting binocular rivalry alternations from brain activity

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When each eye views a different stimulus, visual perception alternates irregularly between them: binocular rivalry. One theory is that: reciprocal inhibition between neurons processing the two stimuli yields active (dominant) and suppressed neurons—we see the stimulus processed by active neurons; adaptation of active neurons eventually reverses activity—perception changes. We know that highly active neurons adapt faster than sluggishly active neurons. Hence, if we had some way of measuring the early activity of the active population, we could predict when a rivalry alternation will take place. We used electroencephalography (EEG) to measure brain activity to a 1000-ms display of dichoptic, orthogonally oriented, sine-wave gratings. Then we turned off both gratings for a 200-ms, dark gap, before showing the same rival gratings for another 1000 ms. We followed this by a mask then an inter-trial interval (ITI). Thirteen participants pressed keys during the ITI of numerous trials to say whether perception changed at the gap or not. Each participant also responded to numerous non-rivalry trials in which the gratings had identical orientations for the two eyes and for which the orientation of both either changed physically at the gap or did not. We found, with simple averaging (rather than requiring pattern classifiers), that greater activity about 180 ms after initial onset of rival stimuli predicted a change in perception more than 1000 ms later, after the gap. We conclude that the predictive activity is consistent with adaptation's being responsible for binocular rivalry alternations.

Acknowledgement: German Research Foundation (DFG RO3061/1–2 and DFG BA877-16)

Visual memory: Neural mechanisms

Wednesday, May 16, 10:45 - 12:45 pm

Talk Session, Royal Palm Ballroom 1-3

Moderator: Timothy Vickery

62.11, *10:45 am*

High-level neural similarity predicts perceptual competition during encoding of different object categories

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Faces, scenes, objects, and bodies evoke distinct but overlapping neural activation patterns in the ventral stream when presented in isolation. If these stimulus categories are presented simultaneously in the visual field, how do they compete for perceptual resources? Is the degree of competition between stimulus categories predicted by the similarity of their individual neural responses? Participants' task was to detect changes between two successively presented displays, each containing four items. These items either came from the same category (e.g. four faces) or a mixture of two categories (e.g. two faces and two scenes). For each category pairing, we compared change detection performance on same-category and mixed-category trials. Overall we found that performance was significantly better for mixed-category than same-category trials, where the size of effect (Cohen's D) depended on the pair of categories tested: F/S=1.24; B/S=1.18; B/F=.97; B/O=.93; F/O=.4; O/S=-.13. Next, we used a blocked fMRI design to obtain activation patterns for each stimulus category for images presented in isolation. Neural similarity was calculated by computing the average Euclidean distance in beta-weights across voxels within independently localized regions of interest (ventral stream excluding V1/V2 and category selective voxels, category selective voxels, areas V1/V2, and dorsolateral prefrontal cortex, DLPFC). We observed a significant ($p<.05$) correlation between the degree of perceptual competition found in the behavioral experiment and neural similarity in the ventral stream ($R2=.5$) and within category selective regions (e.g. FFA+PPA, etc.; $R2=.47$), but not significant in low-level regions (V1/V2. $R2=.03$) or a non-visual region (DLPFC, $R2=.005$). These results show perceptual competition depends on the categories being encoded, and is predicted by the neural similarity of those categories in high-level cortex. These results suggest that the ability to represent multiple objects concurrently is limited by the extent to which representing those objects depend on separate underlying neural resources.

62.12, *11:00 am*

Working memory requirements influence the strength of visual motion direction representations in dorsolateral prefrontal cortex neurons

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When presented with a moving visual stimulus, neurons in macaque area MT encode its motion direction. When the stimulus disappears and its direction is held in working memory, these neurons no longer encode motion direction. In contrast, neurons in the dorsolateral prefrontal cortex (dlPFC) encode motion direction both during the stimulus presentation and during working memory maintenance in the absence of visual input. One question that has not yet been systematically addressed is whether motion direction representations in dlPFC are stronger when the stimulus remains visually available or when it disappears and its direction is remembered. To examine this, we recorded the activity of 155 dlPFC neurons from two macaques while they performed two alternative conditions of a match-to-sample task requiring the comparison between the motion directions of a sample stimulus and a subsequent test stimulus. In the memory condition, the sample was presented for 1 s and, after a delay, followed by the test. In the no-memory condition, the sample remained visible until and during the test presentation, and therefore working memory was not required. For each neuron, we quantified sample direction representation strength using ROC analysis and compared it between the delay period of the memory condition and the equivalent period of the no-memory condition. We found that in approximately half of the direction-selective neurons, representation strength was higher when the sample remained visually available than when it was remembered. Interestingly, in the remaining half, representations were stronger when the sample direction was remembered than when the sample remained present. Our results show not only that dlPFC neurons can encode visual representations in the absence of sensory input, but also that in many neurons, the strength of these representations is in fact reduced in the presence of sensory input, when working memory is not required.

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62.13, *11:15 am*

Working memory for complex objects revealed by fMRI decoding of human visual cortical activity

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Recent neuroimaging studies have found that activity patterns in early visual areas contain content-specific information about the basic visual features that observers are maintaining in visual working memory (Harrison & Tong, 2009; Serences et al., 2009). In the present study, we used multivariate pattern analysis (MVPA) to investigate the role of early visual areas and higher order object-selective areas in working memory for complex objects. On each trial, participants were briefly presented with a specific face and a specific house in randomized order, followed by a central numerical cue indicating which object to retain in working memory. After a 15-s retention interval, a test image from the cued object category was presented, and participants reported whether the test image matched or differed from the initial sample. We analyzed the activity patterns in early visual areas (V1-V4) and object-selective areas (fusiform face area, parahippocampal place area) to predict the category retained in working memory. Reliable information about the remembered object category was found in early visual areas and also object-selective areas. Moreover, an individual time point analysis indicated that this information was actively maintained throughout the 15-s delay period. Remarkably, this object-specific information was preserved despite the fact that overall BOLD activity levels dropped below that of fixation baseline during the delay period. Our results indicate that activity patterns in early visual areas can serve to maintain content-specific information about remembered objects, and that previous fMRI studies may have failed to detect the role of early visual areas due to the lack of an overall increase in BOLD response during working memory delays. These findings suggest that the visual working memory system relies on distributed representations throughout the human visual pathway, including early visual areas, to maintain detailed information about visual objects.

Acknowledgement: NSF grant BCS-0642633, NEI grants R01 EY017082 and P30-EY008126

62.14, *11:30 am*

Temporally specific visual working memory representations revealed by multivoxel pattern analysis

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Visual working memory often requires remembering not only what was seen, but when it was seen. We asked whether temporal features are encoded in visual representations, using fMRI pattern classification and an N-back memory task. While being scanned, participants (N=14) viewed a slow stream of images from three classes (faces, objects, and scenes). Separate runs required either 1-back or 2-back memory tasks. Classifiers were trained to discriminate either the 1-back category or the 2-back category from activity following each trial, and tested using a leave-one-run-out cross-validation procedure. Two broad regions were examined - ventral temporal cortex (VTC: inferior temporal, fusiform, and parahippocampus) and occipital cortex (OCC: all occipital, including lateral occipital cortex). We found that the 1-back item could be significantly decoded in both regions and both tasks. The 2-back item could also be decoded above chance in both regions, but only in the 2-back task. We then examined confusion errors to determine whether this memory was temporally specific. If the decoded features are not temporally specific, then when the classifier made errors during 2-back decoding it should have tended to select the 1-back category, rather than the 3rd (unrepresented) category. Indeed, when the VTC classifier made errors it tended to classify 2-back items according to the 1-back category, suggesting that memory in these regions was not temporally specific. However, when the OCC classifier made errors it did not show a bias to select the 1-back category; in fact, it was more likely to choose the unrepresented category. Thus, despite the fact that 1-back items were robustly represented in OCC, this information was clearly distinct from representations of 2-back items. These results suggest that 2-back tasks induce temporally-specific visual working memory representations in occipital visual regions.

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62.15, *11:45 am*

Maintenance of feature conjunctions in visual working memory: Evidence from response time analysis and event-related potential

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It remains unknown whether feature-integrated object representations are maintained in visual working memory. Previous work suggesting feature-based memory maintenance may be confounded with effects in memory retrieval and matching. The current study used a task without direct judgment on location-specific feature-based matching, and provided evidence for feature-integrated representations. Observers saw a preview display with two colored shapes, followed by a target object at one of the preview locations, and judged whether the target contains any color or shape of preview objects regardless of their locations as quickly as possible. When both color and shape of the target were included in preview objects, task irrelevant feature-location correspondences were systematically manipulated, and their effects were evaluated. Mean RT data showed a pattern supporting feature-based preview benefit by shared location. However, when RT data were decomposed into decision and non-decision components by a diffusion model analysis, estimated non-decision components, presumably reflecting stimulus encoding, revealed a preview benefit based on feature-integrated object representations; a benefit only when both target features shared the location with preview features. This conjunction-specific preview benefit was observed even with moving objects, suggesting that the effect reflects feature-binding in perceptual objects, not only binding at the shared location. Furthermore, to investigate neural correlate of the conjunction-specific preview benefit, an ERP experiment was conducted. Using a display with two placeholders located left and right of fixation, ERP amplitude of N1 component triggered by the target onset at parietal electrodes contralateral to the target reduced only when both target features shared the location with preview features, consistent with the non-decision time data. Taken together, these data indicate that color-shape conjunction, not independent features, facilitates encoding of the subsequent target object, suggesting that a color-shape conjunction bound to a spatiotemporal location is maintained as a unit in visual working memory.

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62.16, *12:00 pm* **Neural signature for the temporal dynamics of online visual object binding.**

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The binding mechanism evaluates incoming information and can integrate several features/objects into a single representation, update existing representations, or create novel object representations. Here, we evaluated the moment-by-moment operations of this mechanism by monitoring the contralateral-delay-activity (CDA, an ERP component indicative of the number of maintained objects). Participants performed the change-detection paradigm, in which colors moved for 1 sec before the retention interval. Motion cues were used in order to indicate either "objecthood" (i.e., 2 colors that moved together) or that the objects were separate (i.e., 2 colors that moved in different directions), creating 4 conditions: two separate objects, four separate objects, 2 color-color conjunction objects, and four separate colors that "met" and became 2 color-color conjunction objects. Across 3 experiments, the results indicated that the color-color conjunction objects were rapidly integrated into bound representations (so that their CDA amplitude was similar to that of two separate colors). In Experiment 1, colors in the "meeting" condition stayed stationary for 100 ms one on top of the other, and the results indicated that the binding mechanism did not integrate them (so that the CDA amplitude was similar to the condition with 4 separate colors), although perceptually these items were identical to the color-color conjunction objects that were integrated into bound representations. In Experiment 2, the meeting colors stayed stationary for 600 ms, one on top of the other after they met, and only high working memory (WM) individuals integrated the items. In Exp 3, the colors met and then moved together for 400 ms. The results indicated that this time, the four colors were integrated into two bound representations (regardless of WM capacity). This demonstrates that the binding mechanism is sensitive to both recency and primacy object information, and that high WM individuals are more likely to override primacy object information.

62.17, *12:15 pm*

The heritability and specificity of change detection ability

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Experiencing a good change blindness task leads easily to questions of whether, how, and why individuals may differ in their tendency to detect or miss changes. Yet our understanding of individual differences in both change detection and its allied domain of visual working memory remain limited. To address this gap in our knowledge, we conducted two large, web-based studies of change detection using a flicker paradigm where a display of blue and yellow dots flashes on and off, over and over, until the participant detects and clicks on the one dot that is alternating from blue to yellow and back. In our first study (n=1542 unselected web participants), we found that the simple time to detect change (TDC) is highly consistent within individuals across trials; therefore, an individual's TDC ability can be captured reliably in under five minutes (Cronbach's alpha reliability = 0.77). TDC also correlated more highly with a visual working memory test than a vocabulary test (r's -0.34 and -0.09, respectively; difference p<0.0001), confirming that TDC performance has more to do with visual working memory than with general intelligence or attentiveness. In our second study, the correlation of TDC amongst 205 monozygotic (MZ) twin pairs (r=0.63) was high relative to the upper bound of 0.77 set by TDC's reliability, indicating that TDC is highly familial. Moreover, the correlation of TDC amongst 113 dizygotic (DZ) twin pairs (r=0.37) was much lower than that amongst MZ twin pairs (difference p<0.001), indicating a substantial genetic influence. In sum, flicker change detection is a specific, heritable ability whose ease of measurement makes it an ideal candidate for use in large-scale molecular genetic as well as focused training and intervention studies.

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62.18, *12:30 pm*

Hybrid search in the temporal domain: Monitoring an RSVP stream for multiple targets held in memory.

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Humans are remarkably good at identifying a target object from a Rapid Serial Visual Presentation (RSVP) of objects or scenes (potter refs). Suppose there is more than one possible target? (Monitor the stream for a cow, a spoon, a pen, or a key). In spatial visual search, Wolfe (Psych Science, in press) has shown that RTs increase linearly with the visual set size but logarithmically with the memory set size. In Experiment 1, we used a staircase procedure to adjust RSVP presentation rate for streams of objects as the observers searched for any of 1-16 target objects. The presentation rate that yielded 80% performance changed logarithmically with memory set size as in spatial search. Now suppose that the memory search item becomes the first target (T1) in an attentional blink (AB) experiment. Would the need to search a larger memory set produce a deeper/longer blink? In Experiment 2, observers saw a stream of numbers with one object (T1) and one red number (T2). They determined whether the object was a member of the target set and they identified the red number. T1 produced an AB for T2. Interestingly, however, we found no evidence of memory set size on T2 performance. Note that in experiment 1, it took ~80 ms longer to classify T1 in a memory set of 16 than in a set of 2. Nevertheless, the engagement with T1 can be compartmentalized in a manner that does not interact with acquisition of T2. Hybrid temporal search provides a new tool for investigating how visual processes and memory processes can operate in parallel.

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Face perception: Development and experience

Wednesday, May 16, 10:45 - 12:45 pm

Talk Session, Royal Palm Ballroom 4-5

Moderator: Isabelle Bülthoff

62.21, *10:45 am*

Infants' perception of the hollow-face illusion: Examining evidence for an inversion effect.

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Last year at VSS, we reported that 6 month-old-infants perceive the hollow-face illusion. Infants reached preferentially to the center of a concave mask during monocular viewing and to the edges of the mask during binocular viewing, indicating that they perceived the mask as convex when viewing it monocularly. However, it is unclear whether infants perceive this illusion as a result of an assumption that faces are convex or a more general convexity assumption. The current study investigated whether the infant visual system makes a face-specific convexity assumption in perceiving the hollow-face illusion. For adults, the illusion is less effective when the mask is inverted than when upright, suggesting that a face-specific convexity assumption plays a role in perceiving that a concave mask is convex. Method: Infants were presented with an upright and an inverted concave mask. Half of the infants viewed the mask monocularly (n=24) and the other half viewed the mask binocularly (n=28). Infants were allowed to reach for the mask and we observed the trajectory of their reaches. Results: Infants in both the upright and inverted conditions reached more often to the center of the display in the monocular condition (61% upright; 65% inverted) than in the binocular condition (15% upright; 16% inverted). Monocular versus binocular comparisons were significant for both the upright (p<0.001) and inverted (p<0.001) conditions. There was no effect of inversion. Conclusion: The results replicate the previous finding that 6-month-old infants perceive the hollow-face illusion. However, unlike adults, we found no evidence of an inversion effect, suggesting that their perception of the hollow-face illusion results from a general assumption that objects tend to be convex, not from an assumption that faces in particular are convex. Future work will examine this question by evaluating the strength of a "hollow potato" illusion

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62.22, *11:00 am*

Holistic Face Deficits in Developmental Prosopagnosia: Abnormal Processing of the Eyes

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Are recognition deficits in prosopagnosia characterized by a lack of holistic face processing? Some reports have shown reduced or no holistic processing in prosopagnosics (Ramon & Rossion, 2010, Avidan, 2011, Palermo, 2011) whereas others demonstrate normal holistic processing patterns (Le Grand, 2006; Bukach, 2006). We addressed this debate more thoroughly with a larger sample of developmental prosopagnosics (DPs; N=30) and a comparable number of healthy controls (N=34). Face recognition ability was assessed using the Cambridge Face Memory Test (CFMT; Duchaine & Nakayama, 2006) and holistic processing through the part-whole test (PW; Tanaka & Farah, 1993). The PW not only allows for overall holistic advantage analysis, but also includes separate eyes, nose, and mouth trials, allowing us to measure how each feature is holistically processed. To

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explore DP's individual differences in holistic processing we contrasted the use of regression, which is more valid in cases where the aim is to statistically remove control task variance (Peter, 1993), against the usual method of subtraction, which creates a measure correlated with both primary and control tasks. Our results show, similar to healthy controls, intact holistic processing of the mouth and nose regions in DPs. However, surprisingly, they show a part over whole advantage for the eyes - a reverse pattern from controls. This indicates that DPs are capable of holistic processing, but only for certain sections of the face. When analyzing individual differences in DPs, we found a significant correlation between CFMT score and holistic processing of the mouth using regression, and a weaker association when using subtraction. Overall our results show that DPs are unable to integrate the eyes into a holistic representation, that their spared holistic processing of the mouth may provide them some small amount of face recognition ability, and that using regression over subtraction, when appropriate, provides a better measure of individual differences.

Acknowledgement: NIH

62.23, *11:15 am*

Recovering sight in adulthood leads to rapid neurofunctional reorganization of visual functions

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Visual deprivation is associated to crossmodal reorganization, leading to the recruitment of the visual cortex for non-visual processing (Bavelier & Neville, 2002). Because of important advances in visual restoration techniques, a crucial question concerns if, how and at what speed the brain of sight-recovery individuals can re-acquire its function to process visual inputs. We used behavioral measures and functional Magnetic Resonance Imaging (fMRI) to explore the potential neuro-functional modifications taking place in the visual cortex of a low-vision (i.e. legally blind) patient (female, 41) before and after partial vision restoration with Boston keratoprosthesis (Dagher & Dohlman, 2008). Behavioral tasks consisted of computerized tests evaluating visual acuity, contrast sensitivity, face perception and global motion perception. Each fMRI session comprised two runs testing the integrity of a key aspect of the ventral (i.e. face perception) and the dorsal (i.e. motion perception) visual pathways. In order to test for crossmodal reorganization, homologous conditions in the auditory modality were also included (i.e. voices in the ventral run; moving sounds in the dorsal run). The patient was tested 6 days before and 3 days following surgery with identical behavioral and fMRI tasks. In parallel to behavioral improvements, fMRI analyses contrasting differential activations before and after visual restoration revealed massive changes in brain responses. Specifically, we found (1) unspecific activity in the occipital cortex for auditory processing pre-surgery, which was reversed (deactivation) post-surgery; (2) enhanced functional tuning to faces in the right ventral visual pathway (fusiform and occipital "face areas", FFA and OFA) after visual restoration and; (3) reduced responses to motion in V5 bilaterally after visual restoration. These observations provide compelling evidence that the human brain maintains a high degree of plasticity well into adulthood, and that the ventral and dorsal visual pathways might be differently affected by visual deprivation and restoration.

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62.24, *11:30 am*

Neural correlates of learning and recognizing faces caricatured in shape or texture

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It has been suggested that the relative contribution of shape compared with texture information to face recognition decreases with increasing familiarity. Extending recent findings of a learning advantage for spatial caricatures, we contrasted effects of spatial and texture caricaturing on face learning and recognition. We assessed performance and event-related potential (ERP) effects in a learning paradigm, using different images at learning and test. Based on a set of 94 faces initially digitized using a 3D system (di3D), 3D caricatures were created by exaggerating shape or colour differences of individual faces from gender matched averaged faces (n = 45 and n = 49 for male and female averages, respectively) at a level of 50%. From caricatured and veridical 3D objects we exported six face stimuli in slightly different views. At learning, 36 participants were presented with faces of 45 different individuals. Fifteen identities each were learned using veridicals, shape or texture caricatures. Each identity was presented in three slightly different views. At test, we presented learned faces in the same condition in which they had been learned, but using three different views. An equal number of veridical and caricatured novel faces was presented and participants performed an old/new task. We found performance benefits for both types of caricatures that were further modulated by familiarity: for learned faces benefits were largest for texture caricatures, whereas novel faces profited most from shape caricaturing. Furthermore, at test we found increased occipitotemporal negativity of N170, P200 and N250 components, as well as a more positive late positive component (LPC), for both types of caricatures. Whereas N170 caricature effects were restricted to novel faces, later caricature effects were not modulated by familiarity. Our results imply that distinctive shape and texture facilitate face learning, with distinctive texture contributing in particular to recognition of learned faces.

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62.25, *11:45 am*

High-resolution imaging of expertise reveals reliable object selectivity in the FFA related to perceptual performance

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fMRI studies at standard-resolution (SR-fMRI) found responses in the fusiform face area (FFA) for non-face objects of expertise, but because high-resolution fMRI (HR-fMRI) in FFA (e.g., Grill-Spector et al., 2006) and neurophysiology in face patches in the monkey brain (Tsao, et al., 2006) reveal no reliable selectivity for objects, FFA responses to objects at SR-fMRI could be due to spatial blurring. As the focus of the strongest claims for modularity and the clearest predictions about expertise, FFA responses to objects of expertise are critical in evaluating the claim that face perception is a "cognitive function with its own private piece of real estate in the brain" (Kanwisher, 2010). Using HR-fMRI at 7 Tesla with a radiofrequency-spoiled 3D FFE acquisition sequence with SENSE, we characterized responses to faces, animals, cars and planes in 25 subjects who varied in car and plane expertise quantified behaviorally. Analyses were performed on flattened cortex. Group-average mean responses replicated prior work, with reliable selectivity for faces and animals but not for objects. However, relating HR signals to expertise, we find that selectivity for objects in FFA increased with expertise, including in the most highly face-selective voxels within the 25 mm2 peak of face selectivity. The proportion of car- or plane-selective voxels in the FFA was also predicted by behavioral expertise, and partial correlations revealed largely independent effects for each category. Critically, FFA responses to objects were restricted to a 200mm2 area centered on the FFA peak. While increased attention with expertise might account for the magnitude of activation, it cannot explain its spatial distribution, which matches the location and size of the patch of face selectivity. Considering individual differences in expertise with HR-fMRI suggests that experience with a category may be sufficient to explain the spatially clustered selectivity for faces observed in this region.

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62.26, *12:00 pm*

What gives a face its ethnicity?

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We can quickly and easily judge faces in terms of their ethnicity. What is the basis for our decision? Other studies have used either eye tracking (e.g., Armann & Bülthoff 2009) or the Bubbles method (e.g., Gosselin & Schyns 2001) in categorization tasks to investigate which facial features are used for sex or identity classification. The first method investigates which parts are preferentially looked at while the latter method shows which facial

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regions, when shown in isolation during the task, leads to correct classification. Here we measured the influence of facial features on ethnicity classification when they are embedded in the face of the other ethnicity. Asian and Caucasian faces of our 3D face database (http://faces.kyb.tuebingen.mpg.de) had been paired according to sex, age and appearance. We used 18 pairs of those Asian-Caucasian faces to create a variety of mixed-race faces. Mixed-race faces were obtained by exchanging one of the following facial features between both faces of a pair: mouth, nose, facial contour, shape, texture (skin) and eyes. We showed original and modified faces one by one in a simple ethnicity classification task. All faces were turned 20 degrees to the side for a more informative view of nose shape, face shape and facial contour while eyes and mouth and general face textures were still fully visible. Because of skin color differences between exchanged parts and original faces, all 3D faces were rendered as grey-level images. The results of 24 Caucasian participants show that the eyes and the texture of a face are major determinants for ethnicity classification, more than face shape and face contour, while mouth and nose had weak influence. Response times showed that participants were faster at classifying less ambiguous faces.

62.27, *12:15 pm*

Individual differences in the visual strategies underlying facial expression categorization

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Having the skills to decode the facial expressions of others is crucial for successful social interactions. Individual differences in this ability exist among the healthy population. We used Bubbles and eye-tracking to investigate how the visual information extraction strategies used for facial expression categorization are related to individual differences in the ability to perform this task. In the Bubbles task, 41 participants (4000 trials per participant) were asked to categorize facial expressions (six basic emotions plus neutral and pain). Sparse versions of these stimuli were created by sampling facial information at random spatial locations and at five non-overlapping spatial frequency bands. For each participant, a classification image showing what information in the stimuli correlated with accuracy was constructed by performing a multiple linear regression on the bubbles locations and accuracy. Subsequently, a group classification image was constructed by calculating a weighted average of all the individual classification images using an index of individual performance as weights (i.e. the number of bubbles necessary to maintain an average accuracy of 61%, transformed into z-scores across participants). We found that the most efficient observers use the left eye area more than the least efficient observers ($r=0.43$, $p<0.05$). An ideal observer analysis showed that the area comprising both eyes is the most informative to discriminate across all expressions, confirming that the most efficient observers use a strategy closer to the ideal one. The eye-tracking task ($N=20$) was identical to the Bubbles task, except that the face stimuli were presented without bubbles. We observed a similar pattern of results: the best participants had a leftward bias in their fixation maps. We propose that the best participants have a more efficient right hemisphere face processor, which allows them to process the most diagnostic information-the eyes-more efficiently, and results in a leftward bias in the information utilization.

62.28, *12:30 pm*

Why do fat faces look thinner upside-down?

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In the VSS 'Best Illusion ' contest 2010, Thompson demonstrated that a face presented upside-down looked markedly thinner than when upright. We now present experiments to investigate this effect. Experiment 1 measured the size of the illusion in 14 subjects with a method of constant stimuli. Comparisons with two upright faces (UU), two inverted faces (II) and one upright and one inverted UI) were made so that psychometric functions could be determined and points of subjective equality (PSE) calculated. This experiment established that upright and inverted faces are not significantly different in their width discriminability, and that an inverted face looks significantly narrower than its upright counterpart. In Experiment 2 we determined that the internal features of the face are responsible for the effect. Again, psychometric functions and PSEs were determined for UU, II and UI conditions, in 13 subjects. The results showed that removing the internal features abolished the illusion. Experiment 3 tested the hypothesis that inverting faces disables the 'holistic' encoding we use for upright faces and hence inverted faces revert to some mean size. We predicted therefore that whereas fat faces look thinner upside-down, thin faces should look fatter upside-down. Nineteen subjects adjusted the width of 12 inverted faces until they appeared to match their upright version. The faces selected varied from those with the widest internal features to those with the narrowest. The results showed that only the two narrowest faces appear fatter when inverted; the remaining 10 faces looked significantly thinner inverted. This suggests that inverted faces do not regress to some 'average'. We shall propose a model that interprets the internal features of the face as a version of the horizontal-vertical illusion, for which it has been reported that a great illusion is seen in an inverted-T than an upright-T (Lee & Freire 1999).

Wednesday Morning Posters

Perceptual organization: Grouping and wholes

Wednesday, May 16, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

63.301 **The regularity after-effect: first or second-order?**

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Aim: Previously we reported a novel uni-directional after-effect termed the regularity after-effect, in which adaptation to a regular pattern caused a slightly less regular pattern to appear even less regular. Here we consider whether the after-effect is mediated by a first- or a second-order process. Method: Stimuli consisted of a 7 by 7 arrangement of elements on a baseline grid windowed through an aperture. The position of each element was randomly jittered from its baseline position by an amount that determined its degree of pattern irregularity. The elements of the pattern consisted of dark Gaussian blobs (GB), difference of Gaussians (DOG) or random binary (RB) patterns. Observers adapted for 60 seconds to a pair of patterns above and below fixation with a different degree of regularity, then adjusted the relative degree of regularity of two subsequently presented test patterns. The size of the after-effect at the PSE was given by the log ratio of the physical element jitter of the two test patterns at the PSE. Results: The after-effect transferred from GB adaptors to both DOG and RB test patterns, and from DOG and RB adaptors to GB patterns. Conclusion: Pattern regularity is an adaptable feature that is encoded by a second-order process. Candidate mechanisms include 1. second-order spatial-frequency channels; 2. the computation of average inter-element distances.

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63.302 **Crowding, Grouping, and the Configural Superiority Effect**

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Visual discrimination is often impaired when irrelevant context items are placed near the target. This crowding effect contrasts sharply with the configural superiority effect (CSE; Pomerantz et al., 1977; Pomerantz & Portillo, 2011), in which adding identical, irrelevant contexts drastically improves the perception of targets (e.g., when discriminating positive from negative diagonals, adding identical Ls to the diagonals creates arrows and triangles that are twice as discriminable as the original diagonals). We asked Ss to locate the target in displays where three quadrants contained identical items while the fourth was odd. The items were line segments varying in orientation (e.g., a single positive diagonal in a field of verticals), and the contexts added to all four quadrants were identical (e.g., a horizontal). We compare discrimination performance against predictions based on the good news (benefits) and the bad news (costs) arising from context. We argue the benefits stem from Emergent Features (EFs) arising from pairs of line segments: Cragin's (2010) study of two-line stimulus space identified 8 EFs arising from simple pairs of lines, including parallelism, symmetry, collinearity, and intersections. E.g., in discriminating a horizontal from verticals, adding an identical to horizontal to each results in discriminating + from =, which is much faster than the original horizontal from vertical because context creates EFs such as intersection and parallelism. In contrast to this CSE, many contexts impair performance; e.g., adding a positive diagonal to a horizontal vs. vertical discrimination impairs performance. Beyond the simple lack of EFs, we attribute these impairments to the added costs from crowding, supplemented by possible adverse effects of masking, increased processing load, and dilution of dissimilarities (Tversky, 1977). We discuss how the costs and benefits mix and assess the claim that crowding is grouping.

63.303 **False Pop Out: Evidence of configural disruption in conventional pop out.**

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False Pop Out (FPO) arises when a distractor stimulus poses as a target in a visual search display with a singleton target among homogeneous distractors. Previous demonstrations of FPO focused on odd-quadrant displays wherein grouping of items in the display yields emergent features such as symmetry that are 'broken' by a distractor, leading to the incorrect identification of that distractor as the target, i.e., as the odd item. For example, in a display of 3 elements like XOX, observers are unlikely to identify one of the Xs odd, but in the equivalent display ()(, they seem more likely to pick the final "(" as odd, because the first two elements group together, leaving the third perceptually isolated. Our current research demonstrates FPO with novel configurations, including displays in which proximity between stimuli is decreased to reduce grouping, displays with rotated quadrants, and linear displays with 3 items arranged in a row). Here FPO is still found to result from configural disruption rather than from any differences in basic featural properties. We propose a metric for quantifying FPO based on non-uniform error distributions across the distractors, such that one of the distractors receives far more responses than any other distractor or even than the actual target. For that distractor, FPO is calculated as a proportion of total error: FPO = ErrorRatedistractor / ErrorRatetotal Our results suggest that conventional pop out does not result from basic feature differences between a target and its distractors but rather from the 'bustication' (disruption) of salient emergent features of the entire, global display. We conclude by demonstrating pop out in heterogeneous displays; despite the fact that all of the items in the display are different, one pops out, and it is the one item that breaks the symmetry or other salient feature of the entire display.

63.304 **Size Perception of Arrays**

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At last year's VSS we presented the Binding Ring Illusion (McCarthy, Kupitz and Caplovitz, 2011) revealing the size of a circular array is subject to assimilation processes. The Binding Ring experiments revealed the outer edges of the array elements serve as a boundary for this assimilation. Is the perceived size of a circular array dictated by this same outer edge? Experiment 1 examined how array element size influences the array's perceived size. Experiment 2 examined how the orientation of triangular elements influences an array's perceived size. Experiment 3 examined the perceived size of circular outlines made of differing outline thicknesses. Results: the size of the array elements has no influence on the perceived size of the array itself. This suggests that either the midpoint or center of gravity of the elements is used as a reference point for constructing the perceived size of the array. The results of the second experiment demonstrated that it is the center of gravity and not the midpoint of the elements that is used. In contrast, when the sizes of two explicitly defined circles are compared, one with a thick outline and one with a thin outline, subjects match the sizes based on the radius of the inner edge of the circles and not the center of the outline contour. Conclusions: the outer edge of a circular array that serves as a boundary for assimilation in the Binding Ring Illusion is not the cue used to construct the perceived size of the array itself. Instead, the perceived size of a circular array is based on the distance between the center of the array and the center of gravity of the array elements. In contrast, the perceived sizes of circular outlines are based on on the center of the outlines but rather their inner radius.

63.305 **Visual apprehension of small and large numerosities in children and adults**

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For small and large numerosities, we evaluated the subitizing capacity, as well as accuracy and precision of visual enumeration across development. We asked children 6 -11 years of age and adults to visually enumerate by "ones" (1-9) or by "tens" (10-90). To analyze whether the ratio differences, 1

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to 2 and 1 to 3, is responsible for enumeration, we compared the accuracies for ratios of 10 to 20 and 10 to 30. We found that enumeration functions of "ones" and "tens" have different characteristics, which is consistent with the presence of two number systems. Across all ages we found a subitizing capacity for 1-3 elements, but not for 10-30 elements. This suggests that subitization is limited to small numerosities (<4 elements) and is independent of the relative ratio between quantities. Responses of children were more variable than adult responses. Counting by "ones," children enumerate similarly to adults, with the exception of 6-7 year olds, who underestimated for numerosities greater than 6. Moreover, when counting by "tens," children disproportionately underestimated relative to adults with the degree of underestimation decreasing as a function of age. These data show that while subitization capacity is adult-like in children 6-7 years of age, enumeration accuracy and precision reaches maturity after 11 years of age.

63.306 **Texture dominates saliency in suprathreshold combinations of texture, colour and luminance.**

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Comparing sensitivities to different cues does not necessarily tell us about their relative saliencies when combined at suprathreshold. Measurements of the relative saliency of combined cues are important as they indicate the relative weightings given by vision to different cues in naturalistic situations, for example in order to highlight warnings. We sought to measure the relative saliencies of combined luminance, colour and texture contrast using a psychophysical task. Stimuli were small circular patches bordered by a thin black line and containing combinations of luminance decrements, purple or red colour contrast, and increments in the contrast of a binary noise texture. The patches were arranged in a diagonal grid on a mid grey background. There were two tasks: 1 'Separate', in which the different cues were presented separately in a two-interval design and participants indicated which interval contained the stronger orientation structure; 2. 'Combined', in which different cues were combined within each patch but arranged to produce competing orientation structure, and participants had to indicate which orientation, and therefore cue, was dominant. We varied the contrast ratio between the cues around suprathreshold baseline levels to find the points of subjective equality in both tasks. Participants required significantly more luminance and colour contrast in the Combined compared to Separate conditions (contrast ratios differed by about 0.1 log units). This result shows that suprathreshold texture is more salient than colour or luminance when the different cues are presented in combination.

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63.307 **Segmentation effects on the tilt illusion: contrast and depth**

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In the tilt illusion, when the orientation of the center and surround gratings differ by a small angle, the center grating appears to tilt away from the surround orientation (repulsion); however, for a large difference in angle, the center appears to tilt towards the surround orientation (attraction). Schwartz et al. (2009) showed that a segmentation model based on the Gaussian Scale Mixture model of natural image statistics in terms of orientation features could account for both attraction and repulsion. We measured the effect of two other sources of segmentation information, contrast and stereo disparity differences between the center and surround, on the strength of the tilt illusion in human observers. By plotting the degree of the tilt bias as a function of the difference in orientation between the center and surround, we observed: 1) when the center contrast was high (70%), both low-contrast surround and stereo depth segmentation cues reduced the amplitude of both the repulsion and attraction effect, relative to a high-contrast, 2D surround; 2) when the center and surround were both low contrast (10%), the repulsion was stronger than in the condition in which they were both 70% contrast; 3) stereo depth cues in this low-contrast condition reduced the repulsion effect but had little effect on attraction; 4) a higher surround contrast relative to the center decreased the repulsion effect but increased both the range and magnitude of the attraction effect. We modified the segmentation model from Schwartz et al. in order to include contrast and depth segmentation features. The probability of perceptual grouping of the center and surround predicted from the psychophysics results by the modified model is consistent with natural scene statistics in terms of contrast features. We also show that the predicted neural population responses are consistent with existing electrophysiology and brain imaging data.

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63.308 **Perceptual modulation of V1 in the bistable translating diamond task is not retinotopically targeted**

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Primary visual cortex (V1) neurons possess small receptive fields and their activity thus represents local scene information. However, many recent studies show that the fMRI response in V1 can be modulated by global scene structure or perceptual changes. Furthermore, perceptual modulation is not always spatially targeted to the region of visual field containing the stimulus (e.g., Williams, Nature Neuroscience, 2008). To understand the retinotopic targeting of V1 modulation during bistable perception, we used fMRI to measure activity in V1 and LOC while subjects viewed a translating diamond stimulus with occluded vertices. This stimulus results in bistable perception of either four lines moving together, with horizontal motion, or two pairs of lines with coordinated vertical motion. Stimuli were presented in an event-related design in which sets of brief presentations of the stimulus (which encourage stable perception) were alternated with extended presentation of the stimulus (which terminated after subjects reported a perceptual transition). This design allows separate analysis of fMRI response during transitions and stable percepts. Separate localizer scans identified retinotopic regions of interest in V1 containing the visible lines. During the transition trials, we measured a negative correlation between the amplitude of the fMRI response in V1 and LOC, consistent with previous reports (Murray et al., PNAS, 2002). However, this negative correlation was not present when analysis was restricted to the region of V1 representing the visible lines, nor was it present during the trials containing stable percepts.

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63.309 **The Impact of Closure on Contour Detection Thresholds in Children and Adults**

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Contour grouping in complex visual scenes requires the integration of disparate elements into a global percept, often despite the absence of local cues to grouping. One of the organizational principles used by the visual system to achieve this computationally difficult task is to perceptually group elements together when the simplest interpretation of the visual input is that the elements form a closed figure. We tested the precocity of 3 to 6 year old children with respect to their ability to use closure as an organizational principle. Both children and adults were tested on a two-alternative forced choice task in which they were asked to indicate which of two visual displays contained a contour. We manipulated both the ratio of the density of the elements on the contour to the density of the noise elements and whether the contour was open or closed. Open and closed contours differed only in terms of the orientation of a single element along the contour path (Q's and O's, respectively). Analysis of reaction time and accuracy data suggested that children performed near chance levels when detecting either type of contour when density of the noise was higher than the contour. For all density conditions, at least some benefit of closure was observed; children and adults were able to use closure information to improve their accuracy and reaction time. Closure became especially important for adults in terms of accuracy at higher densities, suggesting that when simpler mechanisms are sufficient relative to task demands, closure may not be recruited. This study demonstrates that children's ability to integrate visual elements depends fundamentally on the degree to which the Gestalt comprised by those elements stands out relative to distracting cues, and that closed contours are more quickly and accurately detected than even slightly open contours.

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63.310 The Effects of Perceptual Grouping on Saccadic Eye Movements

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GOAL: Perceptual grouping has often been investigated by asking participants to indicate the perceived grouping for stimuli presented at visual fixation. This method of research is unlike how we generally perceive the world, in which we make eye movements to peripheral stimuli for further processing. In this study we therefore examined the influence of perceptual grouping on different properties of goal-directed eye movements. METHOD: In three experiments, participants were instructed to make eye movements from a central fixation symbol to a peripherally presented target (4 to 6 deg), embedded in a background of dots. When the target was presented, for the experimental conditions, the background dots shifted position to form a circle (diameter=3.5 deg) left or right of fixation. In the control condition the dots formed two circles located on either side of fixation or no circle (baseline). Three aspects of eye movements were investigated: Response times, the curvature of the saccade trajectories and landing sites. RESULTS: Based on results from 10-12 subjects we found that response times were faster when a circle emerged around the target compared to when no circle appeared or when the circle appeared on the other side of fixation. Saccade trajectories to targets presented above and below fixation were not influenced by circles left and right of fixation except when the target was above the fixation and the circle was presented near the fixation (at 3 deg). Saccade landing sites were shifted towards the center of the circles when the target was presented inside a circle for leftward, but not rightward saccades. Together these findings suggest that perceptual grouping influences target directed eye movements, but the effects strongly depend on the location of the perceptual group with respect to the target of saccade.

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63.311 Stereo-slant: a novel method for measuring figure-ground assignment

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We present a novel method for measuring figure-ground assignment, based on the observation that the same disparity signal can yield percepts involving different directions of slant depending on how figure-ground is assigned. In figure-ground stimuli containing alternating black and white strips, near disparity was introduced on every other contour (e.g., the left border of each black region). This disparity signal is consistent with the black strips slanted to the right and the white strips slanted to the left. Because adjacent strips share the same border, however, both slant directions are not seen at the same time. Rather the strips of one color are perceived as slanted surfaces, whereas strips of the other color appear as a single frontoparallel surface that extends amodally behind the figural strips. When figure-ground reverses, not only do strips of the other color appear to be in front and slanted, but the perceived direction of slant reverses as well. We manipulated known geometric cues to figure and ground in these displays, including convexity, parallelism, and symmetry (so that one set of strips had one of these properties, but the other did not). Subjects were asked to indicate either which colored regions were slanted, or what the direction of slant was. We found that results with this method nicely tracked these classic figure-ground cues. Our results also suggest that convexity is a substantially stronger cue to figure-ground than either symmetry or parallelism. Our results validate the stereo-slant method as a tool for measuring figure-ground perception, and reveal an interesting interaction between binocular vision and figure-ground perception: regions that are perceived as owning the border also end up "owning" the disparity signal. This can lead to a reversal in the perceived direction of slant when figure and ground switch.

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63.312 The N1 wave amplitude reflects perceptual grouping and correlates with crowding

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In crowding, flanking elements strongly deteriorate performance. For example, vernier offset discrimination is strongly affected by neighboring flankers. Performance is worst when the flankers have the same length as the vernier. Surprisingly, performance improves for longer and shorter flankers [Malania et al., 2007, Journal of Vision, 7(2):1, 1-7]. We proposed that crowding is strongest when the vernier and the flankers group (same length flankers) and weaker when they ungroup (shorter or longer flankers). Here, we used high density EEG to investigate the time course of crowding. First we replicated previous findings. Performance was best in the long flankers condition, intermediate in the short flankers condition, and worst in the medium flankers condition. The P1 wave amplitude correlated with flanker length being highest in the long flankers condition, intermediate in the medium flankers condition, and lowest in the short flankers condition. The N1 wave amplitude correlated well with performance being highest in the long flankers condition, intermediate in the short flankers condition, and lowest in the medium flankers condition. Our study shows that the N1 wave is a good predictor for perceptual grouping and hence crowding. These processes seem to occur after the P1 wave, i.e. after basic feature extraction.

63.313 Grouping by similarity and temporal structure: Evidence for a common mechanism

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What neural mechanisms signal the binding of local image features into global spatial forms? Numerous studies indicate that temporally correlated image changes promote visual grouping, prompting the suggestion that neural synchrony plays a role in binding. However, evidence for the involvement of a similar mechanism for grouping based on non-temporal cues remains limited. In the current study, observers viewed arrays of Gabor patches changing stochastically in spatial frequency. Elements within a central rectangular region changed according to one point process whereas all remaining patches changed according to a second point process, giving rise to a figure defined by temporal structure (TS). On some trials, a similarity cue complemented the TS-defined rectangle: "figure" Gabor patches shared one orientation, whereas "ground" patches shared the orthogonal orientation. On other trials, this similarity cue opposed the TS-defined rectangle: the orientations of the Gabor patches suggested a horizontal rectangle whereas TS suggested a vertical rectangle, or vice versa. In a third condition, the similarity cue was absent: orientations of the Gabor patches were randomly arranged within the array. In all cases, observers' judged the orientation of the rectangle defined by temporal structure. The results suggest that although temporal structure provided a strong basis for grouping—observers accurately identified the orientation of the TS-defined rectangle when the similarity cue was absent or complementary—accurate temporal judgments could not be made in the presence of a conflicting similarity cue, especially as the strength of the temporal cue decreased. These results are consistent with the notion that elements grouped by similarity trigger temporally correlated neural responses, negating the ability to make competing judgments about temporally cued grouping. These findings will be discussed in the context of ongoing debates regarding the role of neural synchrony in the binding of local features into coherent global forms.

63.314 Fundamental properties of simple emergent feature processing

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"Features" of a stimulus object are often specified by certain salient parts of that object (e.g., "eyes" constitute a facial feature). Existing work has provided evidence that "emergent features" such as orientation or proximity may be more salient than "elementary" features like location when two dots are configured in an appropriate fashion using the odd-man-out paradigm. We adapted the original task to a new sequential change detection task. This task had two main advantages. Participants could glean all of the information necessary to complete the task from a single fixation and "false pop-out" effects, induced by configuration of the dots across quadrants, were avoided. In one condition of the double-dot display, the "emergent feature" (i.e. configuration) changed along with location; in another condition the amount of location change was exactly the same, but there was no change in the configuration. In order to replicate the results of previous experiments, we also included uninformative context trials in which one dot is fixed while the other changes location. This will always induce

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a change in configuration. We successfully replicated the results of previous experiments using our new task. Additionally, we applied workload capacity statistics, which assess the performance when the emergent feature is (potentially) present against what can be expected from ordinary parallel processing of the constituent elementary features. The measures are nonparametric and have been shown to be robust and reliable in many other tasks. Using these measures, we found that efficiency is superior to ordinary parallel processing when an emergent feature is contained in the stimulus. Conversely, capacity was hampered when the emergent feature was absent, even though the information given by elementary features was the same in both cases. These results support orientation and proximity as emergent features and rigorously quantify the effect of a change in those features.

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63.315 **Can curved apparent motion be induced by a causal launch?**

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In previous work (Kim, Feldman, & Singh, VSS 2010), we showed that a causal launch, in which one object appears to strike another and cause it to move, can influence the path of apparent motion. In that study, we presented a display of two alternately flashing motion tokens on the ends of a semicircular occluder, with two additional "context objects" that appeared immediately above the two tokens and moved upward at each token onset. In such displays subjects almost exclusively perceive the motion token as moving along the curved path behind the occluder, rather than on the straight path between the two locations. Subjects apparently interpret the motion of the context objects as the result of being struck by the motion token, which implies that the motion token must have been moving out from behind the occluder, forcing a curved-path interpretation. The present studies are intended to extend and generalize these results, and to rule out a potential alternative explanation based on motion priming. We created new displays in which the spatial or temporal pattern of context events was altered in ways that preserved or strengthened motion priming, but weakened the causal interpretation. In one display, both context objects moved upward together in synchrony at every token onset, which is inconsistent with a simple causal launch but primes the vertical motion direction. In another, the upward displacement of the context objects was shifted in time earlier or later, again disrupting the causal interpretation while preserving the strength of priming. Nevertheless in all cases we found that curved apparent motion was observed far more often when it was consistent with a causal launch than when it was not, regardless of priming. We conclude the deviation from straight-path apparent motion is indeed induced by the causal interpretation placed on the collision.

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63.316 **Surround Suppression is Modulated by a "Need for Sameness" Factor Within the Systemizing Trait of Autism**

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The systemizing trait of autism is currently regarded as a uni-dimensional measure of the tendency to analyze the world in a mechanistic, systematic manner (Wheelwright et al., 2006). Recent work has shown that individuals high on the systemizing quotient are less susceptible to a class of visual illusions known to affect an observer's egocentric reference frame (Walter et al., 2009). However, follow-up work (Reed & Dassonville, VSS 2012) using a principal components analysis has uncovered a two-factor structure to the Systemizing Quotient-Revised (SQ-R), with one factor (i.e., 'analytical tendencies') associated with decreased reliance on global-level visual context and the second (i.e., 'need for sameness') associated with an increased reliance on local-level visual information. In an attempt to further characterize the perceptual abilities associated with this two-factor structure, we examined contextual processing using surround suppression, in which the perceived contrast of a central sine-wave grating is reduced when surrounded by a high contrast surround. Past work (Bair et al., 2003) has shown that surround suppression is driven by inhibitory interactions within and between early visual areas (e.g., V1, V2, & MT). Because the 'need for sameness' factor is associated with a local perceptual bias, we predicted that surround suppression would be significantly correlated with scores on the 'need for sameness' factor and unrelated to scores on the 'analytical tendencies' factor. This pattern of results was obtained, with the 'need for sameness' positively correlated with surround suppression susceptibility (individuals high in this factor show increased surround suppression), while 'analytical tendencies' were unrelated to surround suppression. These results further support the hypothesis that the "need for sameness" subcomponent of the systemizing trait of autism is associated with a local visual processing bias.

63.317 **The strength of contextual modulation does not correlate across visual sub-modalities**

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Typically the way that a visual feature is perceived depends on the surrounding spatial context. For example, in the well-known Ebbinghaus illusion, a circle surrounded by larger circles appears smaller. Similarly, the presence of a high-contrast background decreases the apparent contrast of smaller foreground features. Given qualitative similarities among various contextual surround effects (e.g., the effects tend to be repulsive), it might seem intuitive that these processes are related. It is unknown, however, whether contextual modulation processes across visual sub-modalities are independent, or at least in part share a common underlying mechanism. We addressed this question using an individual differences approach. METHODS: A contextual modulation battery was administered to 89 subjects: control subjects (N=17), older adults (N=35) and psychiatric patients (N=37). The context battery included six tasks that assessed surround modulations in luminance, contrast, orientation, motion (2X) and size domains. Staircases were used to measure the amount of surround modulation by adaptively adjusting the relevant dimension of a center target so that it matched a context-free reference target. RESULTS: Robust contextual effects were observed across all tasks and all subject groups, as evidenced by pronounced misperception of center stimulus features. To test for the existence of a common underlying mechanism, we correlated the magnitudes of contextual modulation across different tasks (separately for each group). A common mechanism would predict that a weaker contextual modulation on one task would predict weaker contextual modulation on other tasks. However, we found no significant (uncorrected) correlations for the control group. One significant correlation was found for each special population group (p=0.03), but these should be considerably unreliable given the number of comparisons. Pooled analysis also found no effects. CONCLUSION: We find that strength of contextual modulation does not correlate across visual sub-modalities, suggesting an absence of a common underlying mechanism.

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63.318 **Illusion Susceptibility Indicates a Two-Factor Structure to the Systemizing Trait of Autism**

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The systemizing trait of autism has recently been found to covary with susceptibility to visual illusions driven by contextually-induced distortions of an observer's egocentric frame of reference (Walter et al., 2009). The current study sought to determine whether the relationship between systemizing and illusion susceptibility can be attributed to a heightened processing of local cues, attenuated processing of global cues, or some combination of the two. Scores on the Systemizing Quotient-Revised (SQ-R, Wheelwright et al., 2006) were compared to measures of susceptibility to the Rod-and-Frame illusion (RFI) in a large neurotypical sample. Depending on the size of the illusion-inducing frame, the RFI is thought to be driven by a weighted combination of local, low-level orientation contrast effects (prominent with small frames) and globally-induced distortions of the observer's egocentric reference frame (prominent with large frames). Susceptibilities to these two components of the illusion were measured using recently-developed techniques designed to isolate the two (Dassonville & Williamson, 2010). Higher SQ-R scores were found to be associated with both a decreased tendency to use global contextual cues, and an increased tendency to use local orientation cues. However, susceptibilities to the local and global RFI effects were uncorrelated, suggesting that local processing biases do not necessitate attenuated use of global contextual information. Furthermore, a principal components analysis indicated a two-factor structure to the SQ-R that was differentially predictive of illusion susceptibility. Higher scores on the 'analytical tendencies' factor were associated with decreased global effects of the RFI, while higher scores on the 'need for sameness' factor were associated with increased local effects. These results suggest that the systemizing trait of autism contains a two-factor structure that is differentially predictive of a shift from reliance on global to local visual cues and that, while comorbid in autism, these may be two orthogonal perceptual processes.

63.319 **The Effect of Context and Convexity on Figure Ground Perception in Aging**

Jordan W. Lass[1](jwlass@gmail.com), Patrick J. Bennett[1], Mary A. Peterson[2], Allison B. Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology, University of Arizona

Previous research on figure/ground perception has demonstrated that although convexity typically indicates figure, the context of the border between regions affects the extent to which convexity influences figure/ground perception. Specifically, increasing the number of regions in a stimulus promotes the perception of the convex region as the figure (Peterson & Salvagio, J. Vis., 2008). Although a great deal is known about figure/ground perception in younger observers, it is not clear whether figure/ground perception is affected by aging. Therefore, the current study examined how the effect of context on figure/ground perception is affected by aging. To address this issue, we investigated the effect of region number on figure/ground perception in 10 older (≥60 years) and 11 younger (≤30 years) participants. Subjects viewed brief (100 ms) stimuli from Peterson and Salvagio in which a small red dot appeared either on a white or black region, with convexity equally likely on different polarities across trials, and the task was to say whether the dot appeared on the figure or ground. In separate blocks, stimuli contained either 2 or 8 regions, and different observers started with different conditions. The dependent measure was the proportion of times the convex region was perceived as the figure, and this proportion was compared across groups and conditions. Our results for younger adults replicated those originally found by Peterson and Salvagio: The convexity cue was significantly stronger for 8-region stimuli than for 2-region stimuli. Older subjects showed a general trend in the same direction, however the effect of number of regions was significantly reduced for older subjects. These preliminary results suggest that context affects older observers less than younger observers. Future work will examine the effect of stimulus order and duration to determine, for example, whether older observers can make use of increased context with additional time.

Acknowledgement: Canada Research Chairs Program, Canadian Institutes for Health Research

Perceptual organization: Neural mechanisms and models

Wednesday, May 16, 8:15 - 12:15 pm

Poster Session, Royal Palm Ballroom 6-8

63.322 **Neural correlates of perceptual filling-in: fMRI evidence in the foveal projection zone of patients with central scotoma**

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Patients with juvenile retinal dystrophy often report that they are unaware of their central scotoma, suggesting the presence of perceptual filling-in. We used functional Magnetic Resonance Imaging (fMRI) to determine possible neural correlates of perceptual filling-in in patients with retinal distrophy and clinically established central scotoma in both eyes. The data of 5 patients (Stargardt disease, cone-rod dystrophy; mean age 45 yrs; scotoma diameter 10-20°) and of 5 normally sighted controls were analyzed. Fixation behaviour and perimetry were measured with a Nidek microperimeter. Magnetic resonance imaging was performed using a Siemens 3T Allegra scanner. We stimulated the central visual field (30 deg) with a vertically oriented, low spatial frequency (1 c/deg) high-contrast sinewave grating that was either a) continuous, or b) was interrupted by a central grey disk. The disk was either slightly larger than the scotoma (detectable on 75% of trials) or slightly smaller (detectable on 25% of trials). To control for attention, an eccentric fixation task was performed during scanning. Data were analyzed using SPM8 (GLM with ROI analysis to obtain percent signal change for foveal projection zone). Results: for all patients, the BOLD signal in the foveal projection area was significantly higher for the small disk (i.e., condition leading to complete filling-in) than for the large disk (i.e., no filling-in). This effect was absent in the control subjects. Our findings support the existence of an active neural process that leads to filling-in in patients with central visual field scotomata.

Acknowledgement: DFG: FOR 1075, Project 8 and BaCaTec

63.323 **Resting State Functional-Connectivity Mapping of Putative Visual Cortex in a Blind Patient**

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fMRI signals in visual cortex of human subjects instructed to lie quietly with eyes open (or closed) contain spontaneous, low frequency, fluctuations that are temporally correlated within and across visual areas. Clinically, such functional connectivity MRI (fcMRI) could be particularly advantageous for pre-surgical mapping of viable cortex near a tumor site especially if conventional stimulus-driven mapping cannot be used. Here we report a unique case study of a 26 y/o female who suffered from a large intraventricular mass causing acquired functional blindness but with a preserved fcMRI map of visual cortex. Initially, the patient underwent conventional BOLD fMRI on a 3 Tesla MRI scanner with eyes open and directed toward a back-projection screen displaying a flashing, black and white checkerboard extending from the center of gaze to approximately 20 degrees eccentricity, alternating every 20 sec. with a uniform gray field. The patient could not fixate but was able to look in the direction of the screen so that at least the central portion of the retina was consistently exposed to the stimulus. Nevertheless, visually responsive voxels in the brain were absent. For fcMRI, the patient lay quietly with eyes open but directed toward the uniform gray screen which was on continuously during the 5 min scan. Independent component analysis using MELODIC (FSL) software revealed 3 components containing activation confined to portions of occipito-parietal cortex that, in healthy individuals, are associated with striate and extrastriate visual areas. Overall, the patient's fcMRI patterns matched those of a healthy control imaged and analyzed in an identical manner and those of a cohort of 1414 individuals reported by Biswal et al., 2010 (IC's 01-03). This case demonstrates that fcMRI patterns can remain at least qualitatively intact in the presence of pathology sufficient to block visually driven cortical activity and to cause functional blindness.

Acknowledgement: Suppoerted by R42CA113186, R01EB007827, P30EY001931

63.324 **Different activity in the early stage of the perceptual processing of closed and open figures**

Weina Zhu[1,2](zhuweina_xm@sina.com), Yuanye Ma[2]; [1]School of Information Science, Yunnan University, [2]Kunming Institute of Zoology, Chinese Academy of Sciences

Closure is an emergent perceptual feature that the visual system might extract as a primitive feature of an object. The discrimination of closure is typically faster and easier than that of other geometrical features (Donnelly et al., 1991; Pomerantz et al., 1977; Treisman and Paterson, 1984). The specific nature of closure may be important for the computing object representations. However, there are some questions still unclear: When do closed figures begin deviating from open figures? What is the neural substrate of this perceptual advantage? To investigate these questions, we recorded event-related potentials (ERPs) during a passive observation paradigm. In our study, six pairs of stimuli were used to assess the difference between closed and open figures. Only one of the two figures in each pair was closed, while other low-level features were carefully controlled. We found closed figures deviated from open figures around 110 ms ($t(13) = 2.16$, $P<0.05$), with smaller N1 amplitudes for closed than open figures (-5.3uv vs -8.6uv) at almost identical latency (121.8ms vs. 122.7ms). From these results we propose, compared to open figures, the closed figures need less perception processing at early stages of the visual system. To test this hypothesis, we employed a continuous flash suppression (CFS) paradigm to compare the perception of closed and open figures. Same figures were used in CFS experiment. We find closed figures took less time to be perceived after the suppression (1677ms vs. 1951 ms) at a slightly better accuracy (99.1% vs. 97.9% correct). Our results indicate that, closed figures were discriminated from open figures at around 110 ms. compared to open figures, the closed figures possessed a perceptional advantage and were more rapid to reach awareness during CFS. This was reflected in the ERP traces: closed figures induced smaller N1 amplitudes than open figures.

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63.325 Correlation between Signal Correlations and Noise Correlations among Local Cortical Populations Reveals the Functional Architecture of Early Visual Cortex

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When an identical stimulus is presented repeatedly, the activity of sensory cortical neurons varies from trial to trial, dubbed 'neuronal noise'. Recent electrophysiological and imaging studies reported that 'noise' is not just a random and independent deviation from 'signal' and reflects correlated activity among local cortical sites. Here we investigated the structure of correlated noises in early human visual areas by monitoring moment-to-moment fluctuations in fMRI responses from V1, V2 and V3 during visual stimulation or during a resting state. A signal correlation for a pair of voxels was estimated from a correlation in across-trial-averaged time series of responses to periodic traveling waves of orientation or spatial frequency-modulated stimuli. A noise correlation was estimated from a correlation between two voxels in time series of deviations from their own averages. Individual voxel pairs were also characterized in terms of visuotopic distance via fine-grained population receptive mapping and in terms of distance along cortical surface via segmentation of high-resolution anatomical images. Noise correlations were high for the voxel pairs with high signal correlation (high orientation or spatial frequency tuning similarity), short visuotopic or cortical distance. The analysis of partial correlation, where physical distance factor was held constant, confirmed that the observed functional structure of noise correlation cannot be explained by trivial factors such as spatially correlated MR noises or head motions. Resting-state brain imaging further revealed a significant correlation between noise correlations and correlations in spontaneous BOLD fluctuation, no matter eyes closed or open with fixation on the center of a gray-screen display. Resting-state correlations were highly dependent on signal correlations as the same manner exhibited by noise correlations. Finally, the functional architecture of noise/resting-state correlations was held same both within and between visual areas.

Acknowledgement: This work is supported by WCU program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (R32-10142)

63.326 Interference between fear emotion and topological perception and its neural correlation in amygdala

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This paper reported an interesting, yet counter-intuitive, finding that fear-emotion interfered specifically with the topological perception of holes, a typical kind of topological property. Applying the affective priming paradigm combined with the configural processing paradigm, 12 experiments systematically measured the priming effect of fear-emotion on the discriminability of holes. Both scenery and face served as emotional priming stimuli; a broad spectrum of local geometrical properties (e.g., symmetry, orientation, parallelism, and collinearity) and colors were compared; and presentation conditions, such as durations and making conditions, were varied. Nevertheless, the results consistently showed that fearful pictures significantly increased the RTs with the discriminations of holes. Two more experiments, employing conditioning and backward masking paradigms, strengthened these results by the finding that such interference is specific to fear without being consciously perceived. Angry faces conditioned (CS+) (by shock acoustic), nonconditioned (CS-), and neutral faces were used as priming stimuli, masked by neutral faces. SCRs were also measured. Nevertheless, reliable interferences of CS+ on discriminability of holes were found, while no effects were observed with CS- and neutral faces. fMRI was applied to further measure neural correlation of topological discrimination, contrasting the activation category of topological configural tasks with the baseline category of non-topological ones. The group analysis of fMRI data, using ROIs defined by localizer tasks and by anatomic structures, showed a major activation at right amygdala. As claimed by global-first topological approach, visual processing starts with the extraction of topological properties. On the other hand, fear, as a basic survival mechanism, is considered as one of basic or innate emotions. Viewed from evolutionary perspective, it may become understandable that topological perception and fear activate common brain areas, particularly amygdala. Such interaction between topological perception and fear may open a new window to look into "Where the visual processing begins".

63.327 Motion boundary response domains in awake monkey V2

Ming Chen[1](mingchen@ion.ac.cn), Peichao Li[1], Shude Zhu[1], Chao Han[1], Haoran Xu[1], Yang Fang[1], Jiaming Hu[1], Haidong Lu[1], Anna W. Roe[2]; [1]Institute of Neuroscience, Chinese Academy of Sciences, Shanghai, China, [2]Department of Psychology, Vanderbilt University, Nashville, TN

In the primate visual system, motion information is mainly processed in the dorsal visual pathway (V1 - MT). Recent findings of direction maps in areas V2 and V4, however, suggest that these areas may also play a significant role in motion perception. Perceptually, relative motion is an important source for detection of object boundaries as well as its 3D shape. In this study, we tested the hypothesis that area V2 is involved in detection of motion boundaries and their orientation at a population level. Monkeys were trained to perform a simple eye fixation task. Cortical activities were imaged through a chronic optical window over the visual areasV1 and V2. A motion boundary was created by two random dot patches within which dots were drifting coherently in opposite directions. By comparing cortical responses to horizontal and vertical motion boundaries, we found that there are domains within V2 that are preferentially activated by specific orientation of the motion boundaries. These orientation domains co-localize with regular luminance orientation domains. In comparison, V1 does not have a clear orientation response pattern to the motion boundaries, although pixel-averaged quantification does indicate some weak response in V1. Results from control stimuli indicate that such differences between V1 and V2 were not due to their differences in spatial frequency preferences and point to a V2 locus of motion boundary detection. Such second-order orientation detection mechanism shares the same functional architectures as the luminance orientation maps in V2.

63.328 Background Color Differentially Affects Magno- and Parvocellular Contributions to Conscious and Nonconscious Priming

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Our prior findings (Tapia & Breitmeyer2011) showed that the contrast-dependent effects of primes on reaction time to subsequent probes were determined primarily by activity in the magnocellular (M) pathway when unmasked, visible primes were used and by activity in the parvocellular (P) pathway when masked, invisible primes were used. Contrary to some current theories of conscious and nonconscious visual processing, this indicates an important role of the M and P pathways in conscious and nonconscious vision respectively. Here we followed up on these putative respective roles of the M and P pathways by presenting contrast-varying primes and a probe of high fixed contrast either on a red background or else on an equiluminant green background. Replicating the main finding reported by Tapia and Breitmeyer, results showed that the contrast-dependent priming effects were best described by the contrast-response function characterizing M neurons when primes were visible and by the contrast-response function characterizing P neurons when primes were invisible. Moreover, since the M pathway is known to be suppressed by diffuse red light, we predicted and found that a red background relative to a green one significantly reduced priming effects when visible primes were used but not when invisible ones were used. Both findings constitute additional evidence confirming the contributions of the M and P pathway to conscious and nonconscious vision respectively. Tapia, E., & Breitmeyer, B. G. (2011). Visual consciousness revisited: magno- and parvocellular contributions to conscious and nonconscious vision. Psychological Science, 22, 934-942.)

63.329 A computational study on the representation of curvature constructed from surface-based integration

Yasuhiro Hatori[1], Ko Sakai[1]; [1]Department of Computer Science, University of Tsukuba

Object recognition is achieved through the integration of local features detected in early visual areas. We propose that the construction of surface in the early- to intermediate-level visual areas (V1-V2) contributes to the integration of local cues for the establishment of shape representation in higher visual areas. Physiological studies have shown that a majority of cells in V4 show the selectivity for the curvature and its position with respect to the object center as a primitive representation of shape (Pasupathy & Connor, 2001; 2002), and that the responses of the cells emerge gradually in two phases with the early response to contour fragments and the later response to curvature and its position (Yau et al., VSS2010). We investigated computationally the neural mechanism underlying the curvature selectivity, specifically, whether the responses are established through the integration of contour fragments based on the early representation of surface. We developed a model of V1-V2-V4 networks, and examined the behavior of the integration process and the emergence of the curvature selectivity. The analyses showed that the spatial pooling of V1-cell activities around the CRF center leads to the early phase of the V4 cells, and that the integration of the V1-cell activities based on the surface constructed in V2 corresponds to the late phase. The cellular preference for curvature and its position depended on the directional bias of the integration region with respect to surface. Furthermore, the model V4-cells showed the preference for acute curvature rather than obtuse curvature despite the fact that the model had uniformity in the directional bias, indicating a good agreement with physiology. These results support that the construction of surface in early to intermediate areas plays a crucial role in the integration of contour fragments into curvature for the representation of shape.

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63.330 **Color Helps Isolate Dorsal Stream Contribution to Shape-Recognition Task**

Steven R. Holloway[1](srh@asu.edu), Michael K. McBeath[1], Stephen L. Macknik[2]; [1]Arizona State University, [2]Barrow Neurological Institute

The present study explores the role of motion in the perception of form from dynamic occlusion, employing color to help isolate the contribution of both visual pathways. Although the cells that respond to color cues in the environment usually feed into the ventral stream, humans can perceive motion based on chromatic cues. Additionally, the use of particular colors appears to selectively inhibit the activity in the dorsal system. For example, Seno, Sunaga, and Ito (2010) demonstrated that the color red can have an inhibitory effect on cells engaged in motion-processing. Thus, using the color red as a background feature could be an effective method for investigating magnocellular and parvocellular input in the perception of shapes defined by motion. Moreover, stimuli presented in grey supplies more information to the dorsal stream than a target presented in green and thus should result in color based performance differences. The current study was designed to use grey, green and red stimuli to successively limit the amount of information available to the dorsal stream pathway. Twenty-one participants identified shapes presented in grey, green, and red, defined by dynamic occlusion, and were then presented again in a static condition where the maximum occlusions were presented as before, but without motion. Results confirmed an interaction between the motion and static conditions insofar as when the speed of presentation increased, performance in the motion conditions became significantly less accurate than that of the static conditions. The grey and green motion conditions crossed static performance at the same point, whereas the red motion condition crossed at a much slower speed. These data are consistent with a model of neural processing in which the main visual systems share information; moreover, they support the notion that presenting stimuli in specific colors may help isolate perceptual pathways for scientific investigation.

63.331 **Superposition of Glass Patterns: finding the flow through local measurements**

Daniel Holtmann-Rice[1](daniel.holtmann-rice@yale.edu), Ohad Ben-Shahar[2], Steven Zucker[1]; [1]Department of Computer Science, Yale University, [2]Department of Computer Science, Ben-Gurion University of the Negev

The perception of Glass patterns becomes more crisp as the number of correlated dots increases: patterns made from dot pairs reveal a flow, but it is substantially stronger with triples or quadruplets. At first consideration this relationship between pattern and percept seems to be reflected in simple neurobiological mechanisms: Orientationally-selective cells in visual cortex provide (noisy) estimates of the local orientation, which improve as additional correlated dots are added. A simple selection criterion, e.g. winner-take-all, suffices to select the dominant orientation. The situation becomes more complex when two Glass patterns are superimposed. Superimposing one translational pattern with pairwise dots onto another results in an image perceptually indistinguishable from pure noise. However, with additional correlated dots, the superimposed flows are suddenly revealed. This complex behavior cannot be modeled as easily with the simple mechanism above: winner-take-all can't select multiple values. Furthermore, the perceptual difference between patterns involving dot pairs as opposed to triples is much greater than that between triples and quadruplets, suggesting a non-linear dependence of percept strength on number of dots. We have developed an approach to Glass pattern flow inference based on good continuation that models the above perceptual phenomena. As with visual cortex, the computation is organized around orientation hypercolumns. Information implicit within noisy columns of local orientation estimates is supported by neighboring estimates (in both position and orientation). Differential geometry provides the mathematical framework and, as with textures, the flow is controlled by curvature. The model can be implemented via both long-range horizontal and by feedforward/feedback connections. Experiments with the model show that it properly infers the global flows both in single and superimposed Glass patterns, and that noise is reduced nearly exponentially with additional correlated dots. In effect, the superimposed flows barely interact because of the lift into (position, orientation)-space.

63.332 **An Intuitive Model Framework for Gestalt Grouping Principles**

Nathaniel R Twarog[1](ntwarog@mit.edu), Ruth Rosenholtz[1]; [1]Brain and Cognitive Sciences, Massachusetts Institute of Technology

In Rosenholtz et al. (2009), we presented a model framework for Gestalt grouping principles such as grouping by proximity, similarity, and good continuation. Our approach maps image pixels to points in a higher dimensional space which contains the spatial dimensions of the original image and additional dimensions corresponding to relevant feature values. Thus, using luminance as the relevant feature, pixels that are near one another in the image and have similar luminance would map to points that are near one another in higher dimensional space. One can then group these points by blurring and thresholding this higher dimensional space. Changing the scale of this blur groups pixels across varied spatial scales and feature magnitudes. This approach has the advantage that it operates on images, unlike classical approaches which presuppose foreknowledge of discrete visual elements with well-defined parameters. Unfortunately, this framework lacks any system for generating a single coherent analysis of an image. Human perceptual grouping operates across different scales; to develop the framework into a working model, we must determine how the numerous possible groupings of a scene are culled and cohered into a single organization. To address this, we ran a psychophysical experiment to determine how people perform grouping across a range of scales and luminance differences. In the experiment, subjects are shown two random fields of gray dots, one of which contains a subregion which differs from its background in proximity, luminance, or both. Subjects report which of the two images they believe contained a subregion; accuracy reflects the strength of perceptual grouping. Comparing the results of this experiment with the results of our model framework reveals that the set of parameter settings which contribute the final image organization is complex and highly image dependent, with parameter settings rejected for one image providing the predominant grouping in another.

Acknowledgement: National Eye Institute Training Grant

Multisensory processing: Vision and haptics

Wednesday, May 16, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

63.401 **Pseudo-Haptics using motion-in-depth stimulus and second-order motion stimulus**

Masahiro Ishii[1], Shuichi Sato[1]; [1]University of Toyama

Modification of motion of the mouse cursor during the manipulation by the observer evokes visually induced illusory haptic sensation; backward force sensation arises from deceleration of the cursor and forward from acceleration. Studies have been made on the pseudo haptics using conventional 2D motion. This study investigates the illusion using motion-in-depth and second-order motion. A stereoscopic display and a 3D input/force-feedback device SPIDAR were used in the first experiment. The display was on a frontal plane. Subject was asked to manipulate SPIDAR with his/her right hand and to move a visual target in horizontal, vertical, or front-back direction at a constant speed. Changing image size, disparity, and cast shadow were presented to make front-back motion perception. During the manipulation, the speed of the target was reduced to 50% for 0.4sec. Illusory force sensation was measured using the magnitude estimation method. The result indicates that perceived force from motion-in-depth was about 30% of that from horizontal or vertical motion. We speculated anisotropy of vision or hand motion caused this result. A similar experiment, therefore, was conducted with a different display setup. The display was laid flat on the back and subject was asked to look it down. The illusion from 3D motion was about 30% of that from 2D motion. These results indicate that 3D visual motion weakens the illusion. A random-dot display on a 2D monitor and the SPIDAR were used in the second experiment. The motion cue was second order - in each frame, dots in a square patch reversed in contrast (black dots became white and white dots became black). Subject was asked to move the patch in horizontal direction. The result indicates that perceived haptic sensation from second-order motion was about 90% of that from first-order motion.

Acknowledgement: CREST, JST

63.402 **Varying the visual perspective in which head and finger movement is seen affects cross-modal synchrony detection**

Adria Hoover[1,2](adriah@yorku.ca), Laurence Harris[1,2]; [1]Centre for Vision Research, [2]Department of Psychology, York University

Temporal congruency between different sources of information concerning a self-made movement provides a strong cue for self-identification. Activity in visual body areas in the brain is correlated with self-made movement, implying interconnectivity between visual and proprioceptive information in the representation of the body. We hypothesized that when the viewpoint from which a movement is viewed matches the internal representation, it may result in greater sensitivity to detect a delay between a movement and visual feedback. We therefore looked for variation in this sensitivity with viewpoint to clarify the organization of the visual representation of the body. We measured the threshold and sensitivity (d') for detecting a delay between self-generated movement of the finger or head and visual feedback from various perspectives. For the hand, we compared the natural view with the mirror-reversed and/or inverted view. For the head, the "natural view" was as seen in a mirror. For the back-of-the-head, the "natural view" was from behind the subject. We used a 2AFC paradigm where each trial consisted of one period with a minimum delay and another with a delay of between 1 and 8 video frames (33 ms/frame). Subjects indicated which period contained the delayed view. Sensitivity to detect asynchrony between visual and proprioceptive information was significantly higher when movements were viewed from the "natural view" perspective compared to when the view was reversed or inverted. Further, detection of asynchrony was more sensitive for movements of body parts that are seen most often (hands) than for body parts that are seen only indirectly (face-in-a-mirror) or that are never seen at all (back-of-the-head). Variations in sensitivity to visual/non-visual temporal incongruence with the viewpoint in which a movement is seen may help determine the arrangement of the underlying visual representation of the body.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

63.403 **More realignment for imposed than for naturally occurring biases**

Katinka van der Kooij[1](katinkavanderkooij@gmail.com), Rob van Beers[1], Willemijn Schot[1], Eli Brenner[1], Jeroen Smeets[1]; [1]Faculty of Human Movement Sciences, VU University Amsterdam, Research Institute MOVE

Does the nervous system make lasting corrections for inter-sensory mismatches? Conflicting answers to this question have been given. Research imposing a sensory mismatch has provided evidence that the nervous system realigns the senses, reducing the mismatch. At the same time, research exploiting natural inter-sensory biases provided evidence that the nervous system does not realign the senses. It is unclear whether this difference is due to a difference in experimental approach or whether corrections to natural and imposed mismatches are different. Here, we directly compare how the nervous system corrects for natural biases and imposed mismatches. Subjects moved a hand-held cube to virtual cubes appearing at random locations in 3D space. We alternated test blocks where subjects moved in complete darkness with feedback blocks where we rendered a cube based on the position of the hand-held cube. The first test block allowed us to measure natural biases, whereas subsequent test blocks allowed us to measure realignment to feedback. In feedback blocks, we imposed an eye-centered rotation of plus or minus five degrees on the visual feedback, creating a mismatch between vision and proprioception. We either provided feedback during the movement (continuous feedback) or after the movement had ended (terminal feedback). In this paradigm, endpoint errors are caused by a combination of natural biases and the imposed rotation. Taking advantage of the imposed rotations (-5, +5) canceling each other, we could decompose errors into a component in the direction of a subject's natural bias and a component in the direction of the imposed rotation. We found that there was much more realignment for the imposed mismatch than for the natural biases. This difference in realignment was found with terminal as well as with continuous feedback. Thus, the nervous system corrects differently for imposed and natural mismatches.

63.404 **Visual and Haptic Perception of 3D Shape**

Flip Phillips[1](flip@skidmore.edu), J. Farley Norman[2], Jessica Holmin[2], Amanda Beers[3], Alexandria Boswell[4], Hideko Norman[2]; [1]Skidmore College, [2]Western Kentucky University, [3]McMaster University, [4]University of Nevada, Reno

In the early 1960's Gibson and Caviness performed various experiments on visual and haptic shape discrimination — experiments whose data and detailed results were, unfortunately, never published. Recently, we have acquired and duplicated the original Gibson 'feelie' stimuli using 3D scanning and printing technologies. In these experiments we examine the visual and haptic perception of the feelies along with the well-studied, naturalistic stimuli (bell peppers) of Norman et al. Method: The stimuli consisted of the 10 Gibson feelies and the original set of Norman's 12 bell peppers. The task was a simple same/different shape discrimination using pairs of objects selected randomly on each trial. There were 52 subjects; each judged 50 vision trials and 50 haptic trials. Modality was varied within-subjects while object type was varied between-subjects. For both modalities stimuli were presented sequentially and exploration was limited to three seconds per stimulus. Visual objects were presented via OpenGL depicted with motion, shading, and specular highlights. Haptic objects were explored behind an occluding curtain. For all presentations the objects had a randomly-determined orientation. Results: In terms of discriminability, performance for the bell peppers was higher than for feelies (d' of 2.62 vs 2.03, respectively). Judging the shape of the feelies was more difficult than for the bell peppers ($F1, 50 = 39.7$, $p < .0001$). With regards to modality there was no effect: haptics were equivalent to vision ($d' = 2.35$ haptic vs. $d' = 2.3$ vision, $F1, 50 = 0.34$, $p = .56$). Finally, there was no interaction — overall effect of object type was similar for both modalities. Discussion: For these classes of stimuli there is apparently no effect of modality on performance but the type of object matters. This is likely due to the relative complexities of the stimuli which would be consistent with Phillips et al. previous findings.

63.405 **Visual coding of touch: Gaze direction affects perceived location of touches to the arm, torso, and head**

Lisa Pritchett[1](lmpritch@yorku.ca), Michael Canrevale[1], Laurence Harris[1]; [1]Centre for Vision Research, York University

Gaze position has previously been found to affect the perceived location of visual, auditory, proprioceptive and tactile targets. This is compatible with the idea that perceived target location, regardless of modality, is coded in a visual reference frame and that the gaze angle is systematically underestimated in the coordinate transformations involved in the coding of location. We investigated whether touches to parts of the body that are not in view are also coded in a visual reference frame. Vibrotactile stimuli of 250 Hz and 50 ms duration were applied to the arm, front and back of the torso and to the forehead while the head and/or eyes were held eccentrically. Participants then centered their head and eyes before reporting the perceived location of the touch relative to a visual scale. Perceived touch location was shifted in the same direction as eccentric gaze position for all of the body parts tested, regardless of whether the body part was viewable (arm, front of torso) or not (back, forehead). Eye and head position had equivalent effects, even when the touch was applied to the head. These observations support the idea that touch is first coded in an internal representation of the body that is static and in a canonical position before being recoded into a visual reference frame. Overall, our data suggest that the entire body is coded visually, regardless of whether the body part is viewable.

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63.406 **Prevalence effects on visual search and haptic search**

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In visual search tasks, relative proportions of target-present and target-absent trials have important effects on miss rates and search termination time (target-absent reaction times). Miss rates increase as target prevalence decreases (Wolfe, Horowitz, & Kenner, 2005). This phenomenon is called prevalence effect. Wolfe and Van Wert propose that target prevalence affects the observers' criteria and the quitting threshold (Wolfe & Van Wert, 2010). The observers' criteria govern decisions about individual items during search, while the quitting threshold is related to search termination time. Wolfe and Van Wert suggest that both of these will influence miss rates. Although prevalence effect is observed in vision, there are no studies in other sensory modalities. In this study, we tested whether or not there was the prevalence effect on haptic search and examined the cause of prevalence effect. To compare the prevalence effect on haptic search with visual search, we conducted haptic search tasks and visual search tasks at two levels of prevalence (10% and 50%). We used a tactile map as haptic search tasks and a simulated baggage-screening task as visual search tasks. In our results, prevalence had an effect on miss rates in both search tasks. In haptic search tasks, increase in miss rates in the 10% condition was strongly correlated with a decrement in search termination time. On the other hand, in visual search tasks, we did not find the tradeoff between miss rates and search termination time, as has been reported elsewhere (e.g., Ishibashi, Kita, & Wolfe, in press). Apparently, in these tasks the prevalence effect on haptic search was mainly caused by change in the quitting threshold, while the prevalence effect in the visual search task was mainly caused by a shift in observers' criteria to a strongly conservative position at low prevalence.

63.407 **Haptic shape guides visual search**

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Crossmodal research has shown that information from one sensory modality can influence perceptual and attentional processes in other modalities. Here, we demonstrate a novel crossmodal interaction between haptics and vision, in which haptic shape information influences visual attention. In our study, participants manually explored (unseen) objects and searched for a visual target while we recorded their eye movements. The shape of the manually held object facilitated search for similarly-shaped visual items, whether visual targets were typically graspable in size (e.g., a cell phone, a badge) or not (e.g., a planet, a high rise). This facilitation manifests as a reduction in both overall search times and initial saccade latencies when the haptic shape (e.g., a cone) is consistent with a visual target (e.g., a teepee, a party hat), compared to when it is inconsistent (e.g., a hockey puck, an orange). These haptic-visual facilitative effects occur despite the fact that the manually held shapes are anti-predictive of the visual target's shape, suggesting that this influence is not due to expectation or bias. Additionally, when the haptic shape is consistent with a distracter (instead of the target) in the visual search array, the initial saccades toward the target are disrupted. Together, these results suggest that this crossmodal influence is automatic and demonstrate a robust shape-specific haptic capture of visual attention.

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63.408 **Can shape information be transferred from hand to eye independently of semantics?**

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Is visual object identification influenced by haptic information from objects being explored simultaneously with the hands? Previous approaches to this question have either used familiar objects, thereby not ruling out the semantic route, or used unfamiliar objects, thus neglecting the question of how the results are related to everyday object recognition. Using an adaptation of a visual priming method (Biederman & Cooper, 1991), we compare identity with category priming to separate semantic influences from direct shape transfer in haptic-visual priming with familiar objects. Participants (n=16) manually explored an object (haptic prime) while viewing photos that progressively revealed common objects they were tasked to name. Familiar objects belonged to 8 semantic categories, each represented by 2 differently shaped objects. To address conceptually-mediated versus direct shape priming, we compared identity (haptic prime and visual target share a label and shape) and category priming (same label but different shapes). Results showed that accuracy was greater for identity than category priming (90% vs. 79%), and a shared semantic label led to greater accuracy than in unrelated and neutral conditions (71%). Detailed analyses indicated that the haptic objects did not bias responses independently of these priming effects: (1) with unrelated primes, responses associated with the held object occurred no more (7.8%) than expected by chance (12.5%), and (2) across all conditions in which the haptic prime was a potential target, participants responded with that label only 59% (optimal guessing was 67%). This demonstrates that shape can be transferred from hand to eye for familiar objects, independent of the semantic priming previously demonstrated in haptic-to-visual priming (Reales & Ballesteros, 1999). Moreover, this new methodological approach adds to recent research using non-familiar objects (Ernst et.al., 2007; Ostrovsky et.al., 2011), because it indexes the haptic-visual transfer of shape for familiar, ecologically valid, objects.

63.409 **Smooth pursuit of visible and occluded limbs and grasped tools**

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Research on tool integration has focused on whether structural representations of tools are assimilated into the "body schema", our continually updated unconscious representation of our body's posture and extension. However, little attention has been paid as to whether tool assimilation occurs in how we plan for action. In particular, does the forward model for action assimilate a structural representation of grasped tools? Smooth pursuit (SP) is a result of a predictive forward model that anticipates the direction and the velocity of visual objects. However, SP also occurs when visually tracking one's own hand, even in total darkness. When SP occurs for the hand in the absence of visual input, this is due to a prediction of the direction and velocity of the target from the forward model. Thus, if subjects show greater SP for an occluded tool than an imagined tool, or no stimulus, this would suggest that the forward model also contains a prediction of tool direction and velocity. To test this possibility, we recorded SP eye movements (N = 9) under eight conditions. In four "visible" conditions subjects tracked: (1) a moving dot, (2) their finger, (3) the tip of a grasped rod, and (4) an imaginary rod tip, while grasping a rod handle. In the "occluded" conditions subjects made movements behind a screen displaying dynamic noise. In these conditions they tracked: (5) no movement, (6) their finger, (7) a rod tip, and (8) an imaginary rod tip while grasping a rod handle. As predicted, we found greater SP for the occluded tool condition than in either the occluded tool handle condition ($p < .021$) or the no stimulus condition ($p < .047$). This supports our hypothesis that the forward model assimilates a structural representation of grasped tools into its model of action outcomes.

63.410 **Using mirror box therapy to treat phantom pain in Haitian earthquake victims**

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The day following the devastating 2010 earthquake in Haiti, the queue for amputations was more than 1,000 patients long. Surgeons therefore had to resort to guillotine-style amputations, which may increase the prevalence of phantom limb pain – the vivid impression that the limb is not only still present but extremely painful. We have previously shown (Ramachandran and Rogers-Ramachandran, 1996; Altschuler and Scott, 2011) that mirror box therapy using visual feedback may relieve pain present in a phantom limb. We explored the effectiveness in treating phantom limb pain with mirror box therapy in a disaster stricken area, specifically Port-au-Prince, Haiti. Lower limb patients were recruited from the Hanger Clinic, a prosthetics clinic on the campus of the Albert Schweitzer Hospital. Seventeen out of eighteen lower limb amputees reported a significant reduction in

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phantom pain while using mirror box therapy. The foundation was laid for the on-going practical implementation of this inexpensive and non-intrusive therapy. Further studies might explore how this therapy could best be integrated into the challenging medical environment of the region.

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63.411 **Visuotactile Synchrony is not a Necessary Condition for the Rubber Hand Illusion**

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The rubber hand illusion (RHI) (Botvinick & Cohen, 1998) refers to the illusory sense of ownership of a dummy hand that is viewed while being stroked in sync with stroking of one's hidden real hand. The RHI is considered to stem from interactions between vision, touch, and proprioception. We examined the claim that synchronous visuotactile stimulation is necessary for the induction of RHI. Proprioception of the left arm was measured on 40 trials before and after experimental manipulation, which varied across four conditions. In the main condition, a left rubber hand was presented in a position symmetrical to the right arm that was stationed on a table in front of the participant, and tactile stimulation was applied synchronously to the concealed left hand and the visible rubber hand. The second condition was identical except that stroking was asynchronous between the real hand and rubber hand. In the third condition, the rubber hand was present but no tactile stimulation was applied. In the fourth condition, no rubber hand and no tactile stimulation were presented. A significant proprioceptive shift towards the position of the rubber hand was observed in the synchronous stimulation group, whereas the asynchronous group showed no shift. However surprisingly, the majority of participants who were presented with a rubber hand (i.e., first three conditions) experienced a strong illusion of owning the rubber hand even prior to or in the absence of any tactile stimulation. This illusion was not as strong as that following synchronous tactile stimulation, however it was generally rated as vivid. This finding challenges the notion that tactile stimulation is required for the induction of the RHI. These results are discussed in the framework of a Bayesian inference model combining visual and proprioceptive information and involving a prior expectation for hand position consistent with a canonical posture.

63.412 **Beyond Ramachandran's mirror: A simple video-based intervention for phantom limb pain in unilateral and bilateral amputees**

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Ramachandran and others have shown, in well-known studies, that viewing a mirror reflection of one's moving intact limb reduces phantom limb pain in some single-limb amputees. Also, mirror interventions may enhance recovery from unilateral hemiparesis following stroke and other conditions. However, mirror therapy is ineffective for some single-limb amputees, and cannot treat bilateral amputations or paralysis. Additionally, many single-limb amputees with weak or damaged remaining limbs become fatigued by moving limbs during treatment. I find that a simple video may achieve effects similar to the mirror without causing fatigue, and can extend to bilaterals. First, a video was created of an intact individual's legs and feet, with the individual flexing his ankles, feet, and toes up and down. This flexing was periodic with each cycle occurring every 2 seconds. The flexing was filmed from a subjective point of view, looking down from eye level upon the legs and feet. Patients observed the repeating video loop on a 13-inch laptop computer for ten minutes. Each observer placed the computer on his or her lap and imagined that the flexing limbs were his or her own, and that he or she was causing the flexing. When individuals experienced the illusion of internal (egocentric) locus of control, they experienced strong phantom sensations (paresthesias) and a sense of movement in the missing or paralyzed legs. The intervention led to significant measurable, apparently permanent pain reduction in two bilateral amputees, and two unilateral amputees who had not benefitted from using the simple mirror. A stroke patient reported sensing movement in his paralyzed legs. Some non-amputee normals experience some of the following in their legs while observing the video: tingling, numbness, tickling, pressure, heat, cold, or involuntary movement. Preliminary results suggest that this video technique may enable treatment of individuals who cannot benefit from the simple mirror.

63.413 **Effect of the Range of Motion on the Rubber Hand Illusion**

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Purpose: Rubber hand illusion (RHI) is a phenomenon in which participants mislocate tactile sensations arising from their real hand (which is hidden from view) to a rubber hand. It is one of the important questions whether RHI arises when the angle of the real hand and the rubber hand are incongruent. However there is conflicting results (Honma, Koyama, & Osada, 2009; Tsakiris & Haggard, 2005). This conflict might be caused by no regard of the range of motion of his own body. We investigated an effect of the range of motion of the elbow in transverse plane and coronal plane of the body on RHI. Experiment1: Procedure Participants placed the left real hand on a desk placed horizontally, superimposed left rubber hand produced by 3D computer graphics on the real hand. The rubber hand was presented at eight different angles along transverse plane of the body. The real hand and rubber hand were stimulated simultaneously. Result The strength of RHI when the angle of the rubber hand was congruent with the range of motion of the elbow in transverse plane (an angle of 0, 45 and 90 degrees in clockwise rotation) was higher than when it was incongruent with it (at an angle of 180, 225 and 270 degrees). Similarly, the time taken to elicit RHI at the angle of 0 and 45 degrees of the rubber hand was shorter than at the angle of 225 degrees. Experiment2: We are investigating an effect of the range of motion of the elbow in coronal plane. If RHI arises in the range of motion of the elbow in coronal plane, it is thought that RHI relates to a implicitly matching visual information of rubber hand with a knowledge of the range of motion of his own body.

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63.414 **Onset time of visually induced circular self-motion perception as an indicator for altered self-localization in immersive virtual reality**

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In the framework of the experimental induction of full-body illusions the features of the experience of being a distinct entity (selfhood) are altered such that participants identify with and mis-localize themselves towards a virtual body. On the other hand, it has been found that the experience of circular self-motion, or vection, can be induced by rotating a naturalistic visual environment around human participants. Circular vection is likely influenced by a person's self-localization, since it is the illusion of self-rotation around a specific location. Thus, estimates of vection may serve as indicators for altered self-localization. In the framework of a within-subjects design experiment, male participants viewed an avatar from behind within a naturalistic virtual city in a head-mounted display setup. First, we stroked their back for three minutes while they watched the avatar getting synchronously and congruently stroked, or no visuo-tactile stroking was applied (stimulation factor). Subsequently, we assessed their identification with the avatar with a questionnaire, and then repeated the initial treatment. Finally, we rotated the participants' perspective around their vertical axis for one minute. During rotation the avatar was in the same location in front of the viewer, rotating around his axis, or in a standing posture (avatar-motion factor). Participants were asked to indicate when they started to experience vection. They reported significantly higher identification with the avatar and self-localization in the avatar's position after visuo-tactile stimulation. Moreover, when they experienced visuo-tactile stimulation, regardless of the avatar-motion factor, participants showed a later onset of vection. One possible explanation for these results is that participants perceived themselves as partially localized in the avatar's position, and in turn this decrease in their accuracy of self-localization delayed their experience of circular vection. Consequently, we suggest estimates of self-motion as a new measure for selfhood and embodiment, and specifically for self-localization.

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63.415 **Primary Visual Cortex Activation Responses to Tactile Stimulation in Late-Blind Individuals with Retinitis Pigmentosa**

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Previous fMRI studies suggest that vision deprivation in humans causes the visual cortex to be modulated by the processing of tactile stimuli. This cross-modal activation, if correlated with vision loss, can be used to assess vision restoration progress following sight-recovery treatments. We measured the extent of cross-modal responses in the visual cortex of seven late-blind individuals with retinitis pigmentosa (RP), a genetic degenerative disease that results in gradual tunnel vision and blindness. RP and sighted control groups completed two tactile tasks: a roughness discrimination task using sandpaper discs and a symmetry discrimination task using raised-line shapes. For each subject, we quantified the extent of the tactile-evoked activation by the percentage of significantly activated voxels within V1, and the strength of the activation by the mean absolute modulation amplitude of the activated voxels. These quantities were evaluated as a function of visual-field loss. The strength of the BOLD signal response and percentage of activated voxels within V1 increased with increasing visual-field loss for the sandpaper task (p's <0.05). RP subjects with the greatest degree of vision loss exhibited the strongest visual cortex activation with sandpaper stimulation over the largest cortical extent in V1. For the shapes task, which evoked a weaker response, the order of the means were consistent with that for the sandpaper task, but the differences did not reach significance (p's > 0.10). Comparison of BOLD responses among RP subjects during the sandpaper task revealed a localization of tactile-evoked activity to regions most affected by vision deprivation; greater peripheral vision loss lead to stronger activation in peripheral V1. In summary, V1 responses to tactile stimulation seem to be task dependent. For the task that evoked a strong response, a strong correlation was found between degree and location of visual-field loss with the degree and location of tactile-evoked activation in V1.

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63.416 BDNF Polymorphism Affecting Neural Plasticity Predicts Visuo-Motor Adaptation to Left-Right Visual Reversal

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Introduction. Recent work demonstrates that there may be specific genetic profiles that predict the capacity for neural plasticity. Polymorphisms in the BDNF gene correlate with memory capacity and synaptic plasticity (Egan et al, 2003; Kleim et al, 2006), and may predict capacity for visual-motor learning and motor map plasticity (Pearson-Fuhrhop et al, 2009). Presently, we investigate the effects of short-term adaptation to left-right visual field reversal on visuo-motor task performance with two BDNF genotypes with different propensities for neural plasticity. Methods. The first hour was used to review and sign consent forms, undergo a blood draw for genetic screening for the BDNF val66met polymorphism, and complete a series of short questionnaires. Subjects then spent an hour performing baseline visuo-motor tasks wearing a pair of Control Goggles with a restricted field of view, but no other visual alterations. Finally, subjects spent an hour performing the visuo-motor tasks a second time, this time donning Prism Goggles with right-angle prisms that left-right mirror-reverse subjects' field of view, which was restricted identically to the Control Goggles. The visuo-motor tasks consisted of Finger Tapping, Reaching, and Walking Maze, which were performed in pseudo-randomized order during each hour (except the Maze, which was always last due to increased nausea). Results/Conclusions. On the Finger Tapping task, which is unaffected by the left-right visual reversal, there is no difference in performance between the control and prism conditions, nor a difference between the BDNF genotypes. In contrast, performance on the Reaching and Walking Maze tasks was far worse for the left-right visually reversed condition relative to normal vision for all subjects. Subjects with the val66met polymorphism both initially performed worse and improved more rapidly than subjects with the val66val genotype. These results indicate that there is a differential propensity for neural plasticity between these two BDNF polymorphisms.

Acknowledgement: Institute for Clinical and Translational Science

Attention: Divided

Wednesday, May 16, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

63.417 Different attentional blink tasks reflect distinct information processing limitations: An individual differences approach

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To study the temporal dynamics and capacity-limits of attentional selection and encoding researchers often employ the attentional blink (AB) phenomenon: Subjects' impaired ability to report the second of two targets in a rapid serial visual presentation (RSVP) stream they appear within 200-500ms of one another. The AB has now been the subject of hundreds of scientific investigations and a variety of different dual-target RSVP paradigms have been employed to study this failure of consciousness. The three most common are those where targets are defined categorically from distractors (e.g., report the letter targets that appear amongst digit distractors), those where target definition is based on featural information (e.g., report the red coloured targets that appear amongst the black distractors) and those where there is a set switch between T1 and T2 with the first target typically being featurally defined and T2 requiring a detection or discrimination judgement based on identity or category membership (probe task). An almost universally held assumption across all AB theories is that these three types of task measure the same deficit. Here, across two experiments using large samples and an individual differences approach, we tested this assumption. Subjects performed a variety of AB tasks and all were reliable (test-retest. However, while the ABs found in tasks without a T1-T2 set switch (e.g., featural and categorical AB tasks) and those with a T1-T2 set switch correlated with one another, no relationship in AB magnitude was observed between the these two groups of tasks. Thus, AB paradigms with and without T1-T2 set switches appear to reflect distinct cognitive limitations, suggesting that there are multiple bottlenecks in human information processing that limit temporal attention.

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63.418 The role of spatial and non-spatial attention in MIB

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Motion-induced-blindness (MIB) is an illusory phenomenon where one or more local salient targets surrounded by a moving flow field repeatedly undergo spontaneous disappearances for a short period. There is accumulated evidence indicating that frequency and duration of target disappearance increase when the targets are attended and salient. It has been suggested that the role of attention is to increase competition for selection between the relevant target and the irrelevant distractors (the moving flow field). However it is not clear (1) whether attention is a necessary or only a modulatory factor in MIB, and (2) what form of attention is important – spatial attention or attention to local (target) vs. global (distractor) context. We investigated these questions by studying MIB in a population of brain lesioned patients (N=20), who varied in type and severity of impaired attention. Reflexive spatial attention was assessed by measuring detection of briefly-presented stimuli in the left, right or both hemi-fields. Impairment in context-based attention was assessed with a Navon-like global vs. local letter-identification task. Using standard MIB stimulus and task settings, we measured the frequency of reporting illusory disappearance of local targets. Only patients who showed good detection of real disappearances in at least one hemi-field were included. All patients who showed severe spatial extinction (i.e. a failure to detect briefly-presented stimuli in the affected hemi-field when simultaneously presented with an ipsilesional stimulus) reported few illusory disappearances. For the remaining patients, the frequency of reporting illusory disappearances in the MIB task correlated significantly and positively with the degree of interference from an incongruent salient distractor on target letter detection in the Navon-like task. These findings suggest that (1) [broad] spatial attention is necessary for eliciting MIB, and (2) MIB depends on competition for attentional resources between relevant and irrelevant (but salient) contexts of the scene.

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63.419 **Distraction and Media Use: Not all media usage is created equal**

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Impacts of technology are of high social relevance; yet we have little understanding of which aspects of technology usage may influence distractability. The present study evaluates the counter-intuitive impact of action game play and heavy media multi-tasking on distractibility. Although action-packed first-person shooter video games may not seem to be mind-enhancing, previous work has linked them with better attentional control and better suppression of distractors. In contrast, heavy media multitasking, simultaneously engaging in several types of media, appears to increase susceptibility to distraction. Following the method of Ophir et al. (2009), four tasks were used to test distractibility due to irrelevant information either in the current environment (the Filter test and the AX-CPT test), in memory (an N-back test), or in task-switching. Participants were selected based on action video game experience as well as their level of media multitasking. As in Ophir et al., heavy media multi-taskers (HMMs) displayed inferior abilities to filter out irrelevant information compared to light media multitaskers (LMMs). Additionally, HMMs showed poorer overall performance. In contrast, action video game players (VGPs) exhibited more efficient filtering out of environmental distractors than non action gamers (NVGPs). This was demonstrated by faster reaction times (RT) during the AX-CPT task and greater sensitivity (d') when distraction was the highest in the filter task. When filtering out irrelevant representations in memory during the N-back task, NVGPs had a higher false alarm rate for 3-back than 2-back, as we would expect. VGPs, however, maintained a consistently low false alarm rate. In the Task-switch test, VGPs exhibited faster RTs than NVGPs during both switch and nonswitch trials. Overall, in contrast to HMMs, VGPs appear to implement strategies to make faster decisions, efficiently filtering out irrelevant information regardless of source, while maintaining accuracy similar to or better than NVGPs.

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63.420 **Memory-guided saccading and letter encoding in visual working memory share attentional resources: Evidence from SOA-based interference effects**

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Visual attention (VA) and eye-movement control have a strong functional overlap. In addition it has been hypothesized that VA also serves specific functions for encoding or maintaining visual information in working memory. Carbone and Schneider (2010) found that encoding a briefly presented and backward masked letter into WM slows down execution of a trailing reflexive saccade, suggesting that utilization of VA for control of saccades and for control of WM share attentional resources. In order to further elaborate on this interaction we conducted the following dual-task experiments. Task 1 consisted of a memory-guided saccade to a briefly presented peripheral stimulus (T1). For task 2 participants had to report a briefly presented and backward masked letter at fixation (T2). Importantly, the letter was presented during encoding and retention of the saccade-target location. The main independent variable was the onset asynchrony between the stimuli (SOA) of the two tasks. Half of the participants performed task 2 only, i.e. they were instructed to ignore the stimuli of task 1. The proportion of correct letter identification served as the main dependent measure. We found SOA-based interference on the letter identification (T2) performance in all experiments – similar to the second target deficit in Attentional Blink experiments. That is, performance was diminished with short SOA and increased with SOA duration. Moreover, depending on the competition requirements of task 1 (e.g., memory-guided saccade vs. no task 1) a modulation of the basic SOA-dependent interference effect took place. We conclude that encoding of a location for a memory-guided saccade (T1) and encoding of a trailing and masked letter (T2) into WM share common attentional resources.

Acknowledgement: This research was supported by grants from the Center of Excellence "Cognitive Interaction Technology" (CITEC)

63.421 **Causal evidence for the role of prefrontal cortex in the control of sub- and suprathreshold distracters**

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Previous work has shown that, paradoxically, subthreshold visual motion distracters can disrupt task-relevant performance to a greater extent than suprathreshold distracters. Moreover, activation of the dorsolateral prefrontal cortex (dlPFC) increases for supra- versus subthreshold distracters, suggesting that successful top-down dlPFC control over distracters occurs when they are perceptually suprathreshold. To further investigate, we used the causal approach of applying transcranial magnetic stimulation (TMS) during functional magnetic resonance imaging (fMRI), a technique permitting causal visualisation of the interplay between brain regions under different cognitive conditions; here when motion distracters were presented above or below the perceptual threshold. In 15 participants we applied TMS over right dlPFC as they performed a centrally located visual letter detection task in the presence of task irrelevant moving dots whose motion coherence was manipulated to render them above or below the threshold for coherent motion direction perception. Participants also performed a task in which they were to now report the direction of coherent motion of the (previously irrelevant) moving dot stimuli. As anticipated, when the dots functioned as distracters and were subthreshold, letter task performance was worse and MT+ activity increased. TMS over right dlPFC further activated this region, and also MT+, when suprathreshold motion was present, but interestingly this was regardless of whether motion stimuli were distracters or task relevant. During the letter detection task in visual regions sensitive to the foveal presentation of letters, TMS increased activity but only for suprathreshold moving dot distracters. No such effect was produced when they were subthreshold suggesting that unless distracters are above the perceptual threshold, dlPFC does not influence posterior visual regions. Thus, by combining fMRI concurrently with a causal TMS intervention, we provide a new line of evidence that dlPFC does play a causal role to control interference by communicating with task-relevant versus irrelevant visual regions.

63.422 **Dividing Attention Between Two Transparent Motion Surfaces Results In A Failure Of Selective Attention**

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Introduction: previous research shows that observers can selectively attend to one of two fields of overlapping, transparent moving patterns. We were interested in the extent to which observers could divide attention between two overlapping patterns simultaneously. Methods: we presented two overlapping random dot kinemategrams that varied in both color and motion (e.g. red upward moving dots superimposed with green downward moving dots). Brief decreases in velocity or decreases in luminance could occur simultaneously on both surfaces with 50% probability for a given feature on a given surface. Observers made a yes-no detection judgment of a cued feature. There were three kinds of cues: cues to monitor a specific feature of a single surface (single-task control), cues to divide attention across the two features within the same surface (dual-task within surface), or cues to divide attention between features on different surfaces (dual-task between surfaces). The effect of divided attention was measured as the dual-task deficit: the decline in performance for a dual-task condition relative to the corresponding single-task control. Results: there was little dual-task deficit for the within surface conditions but a large deficit for the between surface conditions. The surprise was that there was also evidence of a failure of selective attention: responses were affected by changes in irrelevant features. This effect was present in all conditions but was most pronounced when attention was divided between the two surfaces. Conclusion: dividing attention between two surfaces therefore results in the failure of selective attention to specific features. Our interpretation is that one cannot simultaneously process two surfaces and must fall back on non-selective processing of the features.

63.423 **Opposite effects of capacity load and resolution load on distractor processing**

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Previous studies suggest that an increased perceptual load decreases distractor processing whereas an increased working memory load increases distractor processing. According to the load theory of attention, an increased perceptual load allows the target to out-compete the distractors at a relatively early stage of processing. In contrast, an increased working memory load interferes with cognitive control, increasing interference at later stages. Here, we suggest that the critical distinction is not between perceptual load and working memory load, but rather between an emphasis on resolution and an emphasis on capacity. That is, perceptual load manipulations typically emphasize resolution (fine-grained discriminations), whereas working memory load manipulations typically emphasize capacity (simultaneous processing of multiple relevant stimuli). To test this hypothesis, we examined the effects of a working memory load that emphasized either the number of items to be stored (capacity load) or the precision of the representations (resolution load). To compare high and low capacity loads, subjects were required to store either 4 colors or 2 colors in working memory to perform a change detection task; the resolution load was minimized by the use of large change magnitudes on change trials. To compare high and low resolution loads, set size was held constant at 2, and subjects were required to detect either small or large color changes. An Eriksen flanker task was presented during the retention interval of the change detection task to assess distractor processing. We found that an increased capacity load led to increased flanker interference (a measure of distractor processing), whereas an increased resolution load led to reduced flanker interference. The latter finding was further replicated with a different manipulation of resolution load. The opposite effects of capacity load and resolution load on distractor processing suggest that working memory load can affect both early and late stages of processing.

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63.424 Access to visual short-term memory is postponed by a concurrent speeded auditory task in the psychological refractory period paradigm

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Previous event-related potential studies have shown that a speeded auditory task interferes with the deployment of visual-spatial attention (as indexed by the N2pc component) and delays encoding into visual short-term memory (as indexed by the SPCN onset latency). However, it is unclear whether the delay of the SPCN reflects postponement or slowing of encoding in visual short-term memory. Since these previous studies only used visual tasks that required the deployment of visual-spatial attention, it is also unclear whether a delay in encoding would occur in absence of a deployment of visual-spatial attention. The goal of the present study was to investigate these two questions. A tone (T1) was presented, followed by a masked visual target (T2). The inter-stimulus interval between T2 and its mask (T2-mask ISI) was 133, 150, 167, or 183 ms. The T1–T2 stimulus onset asynchrony (SOA) was 300, 650, or 1000 ms. A speeded response was required only for T1. T2 was lateralized in Experiment 1 and presented at fixation in Experiment 2. In both experiments. mean reaction time to T1 as well as T1 accuracy were identical in all conditions. In both experiments, T2 accuracy increased as SOA increased, indicating that encoding into visual short-term memory was delayed during the PRP period even when T2 was presented at fixation. As expected, T2 accuracy increased as ISI increased in both experiments. Importantly, the rate at which T2 accuracy increased across ISI did not vary across SOAs, suggesting that speed of encoding was not affected by concurrent central processing in the auditory task. Conditional analysis based on Task1 difficulty corroborated the analyses based on effects of SOA. In sum, results suggest that access to visual short-term memory is postponed by a concurrent speeded auditory task, whether or not the visual task requires deployment of visual-spatial attention.

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63.425 Spatial eccentricity and temporal transition of split attentional foci

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Various investigations have demonstrated that attentional focus is unitary, not splitable, over contiguous regions of space. However, others find that observers can split attentional foci concurrently over noncontiguous regions concurrently (e.g., Awh & Pashler, 2000). Key differences among studies remain unclear. We manipulated the spatial eccentricity of targets and explored temporal transition of attentional foci using Awh and Pashler's (2000) partial report procedure. We also tested whether individual differences in working memory capacity affect the style of deploying attentional foci. Literature shows that individuals with high working memory capacity were able to simultaneously allocate their attention to noncontiguous regions. This leads to the prediction that working memory capacity contributes to differences in the style of deployment of attentional focus/foci. In the present study, prior to the onset of a search display consisted of nontargets (letters) and two targets (digits), two cues appeared at noncontiguous locations either horizontally or vertically. These cues indicated target locations in 80% of the trials. Cues and targets were separated by an SOA (50ms or 750ms) to probe the development of an attentional split, if any, over time. Results demonstrated a split of attention: target identification accuracy was higher at noncontiguous locations relative to those at the intervening uncued locations. This is consistent with results of Awh and Pasher (2000), with the exception that no cueing effect was obtained with vertical cues for short SOAs (50ms). No effect of working memory capacity was found on the split of attention. These results suggest that attentional split develops over time and space regardless of individual differences in working memory capacity.

63.426 Does stress increase or decrease attentional resource? The effect of acute stress on attentional blink

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The notion of attention as a limited resource has been generally accepted. The finding that perception of a second target is impaired after short inter-target lags when two targets are presented in rapid succession supports this position. This phenomenon "attentional blink" is thought to occur because processing the first target deprives attentional resources, leaving no resources for processing the second target when the lag is short. Similarly, acute stress has been viewed as resource consuming by perspectives on stress research that underscore similar capacity approaches. Thus, questions about whether processing a target embedded in a rapid serial presentation and acute stress drain a common attentional resource arise. The present study examined this question by manipulating inter-target lag and stress. The resource-depletion theories involving attentional blink predict an increased blink effect, whereas the overinvestment view predicts a decreased blink. Participants identified two targets embedded in a rapid stream of nontargets separated by variable numbers of intervening nontargets (lags of 100-700 ms). Participants in the stress group received the Trier Social Stress Test, which generates speech anxiety and threatens self-esteem. The control group received a filler task. The stress induction successfully increased scores on the State-Trait Anxiety Inventory and levels of salivary cortisol from before to after stress induction. Both groups exhibited attentional blink: accurate identification of the second target was impaired at shorter lags. The effect of lag interacted with the stress manipulation. Participants in the stress group demonstrated greater attentional blink relative to those in the control group. The present results are consistent with resource theories, rather than with the overinvestment view. The results suggest that target identification and stress drain the same attentional resource, resulting in increased attentional blink under stress.

Attention: Capture II

Wednesday, May 16, 8:15 - 12:15 pm

Poster Session, Orchid Ballroom

63.427 Attentional Capture is attenuated after experience with diverse distractor features

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Past research has shown participants were able to ignore salient distractors when encouraged to use a specific target template (Bacon & Egeth, 1994). Recent work from our lab qualified these results by demonstrating that participants not only needed a specific target template, but they also needed experience with salient distractors in order to prevent capture (Vatterott & Vecera, 2011). Our results suggested that participants needed experience with each specific salient distractor in order to prevent capture by it, but this may not be the case. Research in learning has found that variability in the environment can enhance the ability to generalize learning to novel situations (Schmidt & Bjork, 1992). This suggests that if participants are given more variability in salient distractors, they may be able to generalize distractor rejection to novel salient distractors. To investigate this possibility, participants completed a search task with three different salient distractors present on half the trials over three blocks. Critically, participants were assigned to one of two groups: one group (within-block) was presented with all three color singletons intermixed within three blocks, the other group (between-block) was presented with a different color singleton in each of the three blocks. The critical trials came in the fourth block when both groups were presented with a novel salient distractor on half the trials. We hypothesized that if variability aids in the ability to generalize distractor rejection, capture in the 4th block should be attenuated for the within-block group compared to the between-block group. In line with this hypothesis, the novel singleton did not initially capture attention in the within-block group while there was a significant attentional capture in the between-block group. These results indicate that experience with a specific color singleton is not necessary for efficient rejection of that singleton.

63.428 Arresting perception: Animate objects capture attention and 'slow' time

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In the increasing consideration of biological relevance to perception, stimuli such as spiders, angry faces, and even animate objects categorically (humans and nonhuman animals) have proven robustly capable of capturing visual attention. We examined how increased attention to one such category, animate objects, may also augment their representation in visual awareness. We proposed that such an enhanced representation could be experienced as having a subjectively prolonged duration (exceeding its physical duration), termed subjective time dilation. We predicted that the duration of briefly-displayed people and animals (both previously shown to be prioritized for visual attention) will more often than inanimate objects appear greater than their veridical duration. We tested this prediction with the 'oddball' paradigm: the duration of an attention-capturing stimulus in an image series often appears longer than the other stimuli, even when displayed for less time than the other images all shown for the 'standard' duration. One item from one natural category (people, animals, flowers, or vehicles) was presented amongst urban and rural landscapes and ranged in duration from half to slightly longer than the standard duration. Participants simply identified which item in each stream of images was displayed for a 'longer' amount of time than the others. Animate objects were identified as the 'longer' images in the sequences far more frequently than chance –and significantly more frequently than the inanimate targets – even when presented for 50% of the standard duration. Additional experiments ruled out that the subjectively prolonged duration of animate objects resulted from differences in lower-level visual characteristics or dissimilarities from the distractor images. Brief glimpses of biologically relevant objects may thus be more persistently represented in visual awareness than other types of objects. These studies additionally demonstrate how subjective time dilation and duration estimation can be employed as a novel and implicit metric of attentional capture.

63.429 Greater sensitivity to visual motion predicts a greater capacity to ignore it

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Efficient visual search performance sometimes demands exquisite sensitivity to very subtle changes in our environment, while at other times demands that we ignore highly salient information. How are these seemingly divergent processes linked? One clue comes from a recent study showing that individuals with greater evoked fMRI activity from passively viewed motion exhibited greater behavioral distraction in a separate task when the motion was to be ignored (Lechak & Leber, under revision). This suggests that greater sensitivity to visual motion makes one less able to resist processing it. To directly test this possibility in the current study, we examined the relationship between an individual's psychophysical motion sensitivity threshold and a measure of behavioral distraction. To obtain motion thresholds, observers completed a two-interval forced choice task in which coherent motion was to be discriminated from random dot motion. Dots in the coherent interval were varied in coherence from 4% to 50%, and an accuracy threshold of 75% was estimated for each observer. To obtain the distraction measure, observers searched 10-item displays for a target square among circles and reported whether the target had a gap in the top or bottom. On 50% of the trials a moving distractor singleton appeared 50 ms before target onset. RT on these trials was compared to RT on distractor-absent trials to yield a behavioral distraction index. Results showed a positive correlation between coherence thresholds and the distraction index, $r = 0.52$, $p = 0.023$. That is, observers who were less sensitive to visual motion were less able to ignore salient distracting motion. These results are inconsistent with the proposal that greater sensitivity to motion makes one less able to resist it. Instead, an individual's ability to enhance processing of task-relevant stimuli and suppress processing of irrelevant stimuli could be subserved by a common mechanism.

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63.430 Attentional capture with and without awareness

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We have shown that attentional capture by static color feature is contingent on top-down controls; whereas attentional capture by transient visual onset can be purely stimulus-driven (Liao & Yeh, 2011, Acta Psychologica, 138, 52-59). Assuming that top-down modulation is more effective for visible than invisible stimulus, we hypothesize that attentional capture is susceptible to stimulus visibility for color, but not onset. In a spatial cueing paradigm, a color target was preceded by an onset or color cue. The cue visibility was manipulated by the presentation duration—50 ms (visible) and 17 ms (invisible)—followed by a location mask, and verified by individual participant after the experiment. Attentional capture was inferred by faster responses when the target appeared at the same location as the precue than at different locations. Results showed that both invisible color and onset cues captured attention, indicating attentional capture without awareness. Most importantly, attentional capture by color was larger when the color cue was visible than invisible; however, attentional capture by onset was independent of the onset cue's visibility. The overall results suggest that attentional orienting toward a feature that is contingent on the task goal is modulated by feature-based top-down controls. By contrast, bottom-up attention is sensitive to transient visual onset and independent of top-down controls.

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63.431 Distracter rejection depends on mechanisms of attentional shifting

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The ability to limit distracter interference is an essential aspect of attentional control. However, the mechanisms by which we actively reject non-target objects that have already captured our attention (e.g., a tomato when looking for an apple) are unknown. We hypothesize that the ability to reactively reject non-targets depends upon the ability to control attentional shifting (cf. attentional focus). We tested the relationship between attentional capture by target-similar objects and the ability to reactively shift attention in two experiments. In experiment 1, subjects engaged in a detection task for a target defined by a conjunction of color (e.g., orange) and location (e.g., on the left). On some trials, a target-colored item appeared in an irrelevant location; on those trials, subjects were slower to decide that a target was absent than when the target-colored item was absent. Interestingly, the RT cost of attentional capture by the target-colored distracter was negatively correlated with the individual ability to control attentional shifting, but not to control attentional focus, as measured by the Derryberry Attentional Control Scale. The ability to limit interference by the target-colored distracter was related to an individual's ability to shift attention; in contrast, better ability to focus attention did not correlate with improved distracter suppression. In experiment 2, we used a visual search task where the target was defined by a conjunction of color and the location of a "gap". In this study, eye-movements were used as an index of attention. We found that the ability to reject distracters by shifting attention depended not only on the similarity of the item with the target, but also the presence of alternative potential targets. This suggests that the ability to reject a distracter is an active process that is associated with selection mechanisms that drive attention towards other goal-relevant objects.

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63.432 **Feature singletons and single cues both enhance contrast sensitivity**

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Goal: Objects appearing in the visual periphery can automatically capture attention. The brief flash of a single cue, for example, rapidly enhances contrast sensitivity for subsequent stimuli in its vicinity. Feature singletons (e.g., a red shape among green ones) can also capture attention in a variety of tasks. Here, we evaluate whether a peripheral cue that enhances contrast sensitivity when it appears alone has a similar effect when it appears as a color singleton, with the same stimuli and task. Methods: Observers discriminated the orientation of a Gabor patch that appeared at one of two isoeccentric locations on opposite sides of an imaginary 45º diagonal. A red or green cue disc was flashed 106 ms before the Gabor's onset, either near the Gabor's location (valid cue, 50% likely) or near the opposite location (invalid cue). In a random half of trials the cue disc appeared alone, and in the remainder it was presented amongst 15 others of the opposite hue, all arranged in an isoeccentric ring. The discs' colors were equated in subjective luminance. Observers were explicitly informed that all the discs were task-irrelevant. Results: By varying the contrast of the Gabor we obtained psychometric functions of sensitivity (d'). For both cue types, sensitivity was higher on valid trials than on invalid trials, as evident in estimates of c50 (single cue) or asymptotic d' (singleton). In the single cue condition, attention was drawn towards the location of unique contrast change against the background. In the singleton condition, attention was drawn towards the disc with chromatic contrast relative to all other discs in the display. Thus, feature singletons and single cues enhance early visual processing in different ways.

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63.433 **On the Precision of Attention Sets: The Effects of Spatial Context and Distractor Multiplicity on Contingent Capture**

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The contingent spatial blink paradigm, developed by Folk, Leber, and Egeth (2002), demonstrates a deficit in precision when maintaining attention goals (sets). A completely irrelevant target-colored distractor presented with an RSVP (rapid serial visual presentation) stream induces a substantial attention capture effect, even when this distractor is distant from the RSVP stream and the target's location is central and constant. We first performed an experiment to determine whether attention set precision could be improved by providing spatial context. The target and target-colored distractor either both appeared within one of two boundary boxes or in separate boxes. We hypothesized that when the target and same-color distractor were separated by spatial context, capture would be diminished. Supporting this hypothesis, results show that capture was reduced when the items were separated (M = 71.7% accuracy) compared to when they appeared within the same box (M = 63.4%), but this contextual exclusion was not sufficient enough to fully eliminate capture. Our second experiment examined whether holding an attention set for both color and number, since the target is a single red item, would prevent capture when multiple target-colored distractors were introduced. On critical trials, one target-colored distractor could appear at a random peripheral location, two such distractors could appear at adjacent locations, or these two distractors could appear at opposite locations. We hypothesized that multiple target-colored distractors would produce less capture than a single target-colored distractor since they do not fulfill the characteristic of oneness. Results revealed that adjacently positioned distractors (M = 62.4%) and oppositely positioned top-bottom distractors (M = 60.5%) behaved similarly to a single distractor (M = 64.0%). Surprisingly, opposite left-right (M = 52.8%) distractors actually produced greater capture. Both experiments demonstrate the limitation of attention set precision, but show how spatial and contextual factors can modulate contingent capture.

63.434 **Irrelevant faces do not capture spatial attention in RSVP sequences**

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Emotional faces are very engaging and are proposed to capture attention in spatial tasks (Eastwood, Smilek, & Merikle, 2003). Uniquely-coloured distractors can also capture attention, and can do so even when attention is maintained in a highly-focused state at a known target location, such as when identifying a target letter from an RSVP sequence of distractor letters (Folk, Leber, & Egeth, 2002). Here we examine whether emotional faces can capture attention when attention is highly focused at a known target location. In Experiment 1 a sequence of black letters was presented in an RSVP sequence. Two straight lines and a curve, which either formed an emotional face or a meaningless group (T1) surrounded one black letter. Subjects reported the identity of one red letter (T2) presented at various temporal lags from T1. Attention was captured by the perceptual groups only when they were red, leading to impaired T2 identification at short lags; distractors forming an emotional face, however, were no more detrimental to T2 identification. In Experiment 2 distractor letters were omitted from the sequence in the positions before, during, and immediately after the perceptual group. Meaning again did not influence T2 identification. In Experiment 3 subjects performed visual search for a target (a perceptual group, or a letter within a perceptual group), presented in a static array with other meaningless distractor perceptual groups, one of which sometimes formed an emotional face. The presence of an emotional face slowed response times for letter targets within perceptual groups, but not for perceptual groups themselves. The results indicate that a strict filter is adopted by the attentional system to cope with the heavy demands imposed by the RSVP paradigm. Consequently, emotional faces do not capture attention when it is narrowly focused, but do so when attention is broadly distributed.

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63.435 **Ignoring a salient distractor: feature-based inhibition or object-file updating?**

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The mechanisms that allow us to ignore salient visual information when it is irrelevant to the observer's attentional set have been debated. Using variants of Folk, Remington and Johnston's (1992) spatial cueing task some authors have shown that in search for a color-defined target, an irrelevant-color precue does not affect performance (e.g., Folk & Remington, 1998), suggesting that it is simply filtered out. Others have reported a same-location cost: they showed that an irrelevant-color precue delays response when it appears at the same vs. at a different location relative to the target (e.g., Lamy & Egeth, 2003) and suggested that this effect reflects top-down inhibition of the ignored salient feature. Hidden formatting deleted. Delete this text! left;line-height:normal”>In the present study we reevaluated these claims and delineated the boundary conditions of the same-location cost. We found that the same-location cost is largely independent of feature-based selection, suggesting that feature-based inhibition does not account for all the effect, if at all. In addition, the effect did not disappear when precue-to-target onset asynchrony was increased, thus precluding a masking account. Finally, the same-location cost was substantially reduced when the spatio-temporal continuity between the precue and target was disrupted. Although spatio-temporal object continuity and disruption thereof have been shown to have a cardinal impact on perception, their potential role in central findings of the attentional capture literature has not been considered. The present findings open the possibility that processes related to the updating of the information associated with an object across space and time may account for effects that have traditionally been attributed to goal-directed attention.

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63.436 **Collinearity Distractor Impairs Local Visual Search**

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In visual search, a target's appearance and spatial arrangement in relation to neighboring elements jointly modulate its salience and affect search efficiency. For example, a vertical bar sitting among horizontal distractors captures attention, while stimuli following the law of good continuity highlight and prioritize the global structure. Here we report a combination of the two factors above (high orientation contrast and salient global structure) actually impairs search for a local element. Method In a display containing 21 x 27 short horizontal bars, we rotated all of the units in one column by 90 degrees to form a salient vertical collinear structure. The task required observers to search for a small tilted gap that broke one of the bars, which may overlap the salient column (overlapping targets) by chance. In other words, the collinear column was not informative to target search and was therefore task-irrelevant. Results and Discussion Our result showed that the discrimination of gap orientation was slower and less accurate for overlapping targets in comparison with non-overlapping targets. In five experiments, we demonstrated that collinearaity was the major cause of this impairment regardless of local or global orientation. We conjecture that when organized by collinear elements, the global structure forms a strong "objecthood", which captures attention but which also overshadows the conspicuousness of a local element within. Further studies are needed to identify if this conjecture can be expanded beyond collinearity to broader Gestalt grouping laws. Whereas it is conventional knowledge that global structures enhance target search, our experiments pioneer in revealing that such structures can also impair the search process. The empirical evidence signifies that interactions between perceptual grouping and salience search are more complicated than we have previously imagined.

63.437 **Contingent attentional capture depends on cue probability in singleton search mode but not in feature search mode.**

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Some studies suggest that attentional selection is determined by top-down search intentions whereas others show the impact of bottom-up saliency signals. In the additional singleton paradigm, attention is oriented to a color singleton because of its saliency and despite observers' intention to search for a form singleton. In contrast, attentional capture in the modified spatial cueing paradigm only occurs when the color of a salient singleton in the cue display is equal to the color of a singleton in the subsequent target display. That is, salient objects only capture attention when they correspond to observers' search intention. Recently, Müller, Geyer, Zehetleitner, and Krummenacher (2009) showed in the additional singleton paradigm that capture by a salient but irrelevant singleton depends on its probability: Capture increased when the probability of the irrelevant singleton decreased. We investigated effects of cue probability in a version of the modified spatial cueing paradigm (Folk & Remington, 1998). The target had a different color from the cue so that search intentions did not correspond to the feature of the cue singleton. Because of the mismatch, only weak attentional capture was expected. In Experiment 1, however, significant capture was observed. The capture effect was larger when the cue singleton occurred on only 25% of the trials than when it appeared on 100% of the trials. In Experiment 2, a second color singleton in the target display was added, forcing feature search. When the cue singleton occurred on 25% of the trials, no capture was observed. When it occurred on 100% of the trials, the effect was small. Importantly, there was no difference between the 25% and 100% condition in feature search mode. Our results suggest that salient objects with low-probability may override search intentions in singleton search mode, but not in feature search mode.

63.438 **Stimulus-driven attentional capture by task-irrelevant optic flow**

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Researchers have debated about whether the deployment of visual attention is dependent on stimulus saliency or on attentional set. Studies supporting the latter view have used static features and have found that attention is captured only when task-irrelevant stimuli (distractors) share features with the target. Although several recent studies have included dynamic attributes, investigations have been limited to transient changes or the translation of local independent objects. Given that the visual system is sensitive to global signals such as optic flow, which is vital for locomotion, it is conceivable that global motion would be able to capture attention irrespective of attentional set. Thus, we investigated whether task-irrelevant optic flow captured attention when participants searched for a target defined by a specific color. The stimulus display consisted of 2,000 dots and a rapid stream of letters in the center. Observers searched for a green letter embedded in heterogeneously colored letters. The dots expanded or contracted for 100 ms at 300 ms or at 100 ms before or after the presentation of a target. A control condition, under which the dots remained static, was also included. The results indicated that correct identification of the target was significantly impaired when the optic flow expanded 300 ms before target onset. A subsequent experiment revealed that an abrupt cessation, rather than an abrupt onset, of optic flow also impaired target identification when it occurred 300 ms before target onset. However, neither acceleration nor deceleration in the range of half to double the speed caused any significant decrement in target identification. We conclude that salient discontinuities in global motion induce attentional capture when observers engage in feature-search mode in a different stimulus domain.

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63.439 **Effects of stimulus identity and load in working memory on visual search: Eliminating the effect of load but not identity by lengthening encoding time**

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Although there is now considerable evidence that working memory (WM) interacts with perception to select information for action that is consistent with the current goal set, the conditions under which these effects arise remain unclear. Here effects of the identity and load of items in WM on visual attention were examined. The load was manipulated by contrasting top-down cuing from WM with the effects of mere repetition from a cue (WM vs MR condition). With a short interval between the WM item and a subsequent search task, there were effects of both load (slowed overall RTs in a WM condition relative to a MR baseline) and identity (search RTs were affected by re-presentation of the item in WM in the search display). As the time to encode the initial display increased, the effects of load decreased while the effect of identity remained. The data indicate that the identity of stimuli in WM can affect the subsequent deployment of attention even when time is allowed for consolidation of the stimuli in WM, and that the WM effects are not causally related to the presence of cognitive load. The results are consistent with the identity of stimuli in WM modulating subsequently attention post the consolidation stage.

63.440 **Own-race faces capture more attention than other race faces: Evidence from response time and N2pc**

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Plenty of studies have shown that people are better able to recognize the faces of people from their own race than the faces of people from other races. Some researchers explain the so-called own-race advantage (ORA) in terms of categorization versus individuation (Sporer, 2001; Hugenberg, Young, Bernstein, & Sacco, 2010). Perceivers only encode the category information of the out-group members without further processing; while processing the detailed individual facial features of in-group members. The categorization tendency to other-race faces was supported by a race search task of Levin (1996, 2000) which found that White participants detected Black face among White faces faster than detected White face among Black faces. In the present study, we used a human search task, which rules out the influence of categorization and individuation, to investigate whether ORA occurred in attention. Participants' task was to search a human face among animal faces. Experiment 1 showed a classic searching asymmetry effect with an ORA in response time (RT). Experiment 2 recorded event-related potentials, and replicated the ORA in response time and extended the results to inverted faces. We also found a larger N2pc wave evoked by own-race faces than other-race faces. Moreover, there was a significant positive relation between N2pc and RT. Faster detection of own-race faces was observed with larger N2pc waveform. These results suggested an own-race attentional capture advantage, providing evidence for an attentional account for ORA.

Development: Neural mechanisms, models and disorders

Wednesday, May 16, 8:15 - 12:15 pm
Poster Session, Orchid Ballroom

63.441 A substantial and unexpected enhancement of motion perception in children with autism spectrum disorders.

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INTRODUCTION: Motion perception deficits in autism spectrum disorders (ASD) are well documented. For example, ASD observers show higher motion coherence thresholds and impaired processing of biological motion stimuli. ASD is also associated with impairments in contextual processing of sensory information. These two lines of research motivated us to investigate the effects of stimulus size on motion perception in ASD. Typical observers show a surprising decrease in motion visibility of large, high-contrast stimuli — a contextual modulation termed spatial suppression. METHODS: We measured motion discriminations for stimuli of different sizes (1°, 2.5° and 6°) in children with ASD (N=11) and typical development (N=14), matched for age and IQ. Stimuli (4Hz; 1cyc/°; 93% contrast) were presented foveally. Adaptive staircases were used to estimate duration thresholds. RESULTS: As expected, we found that thresholds increased with stimulus size ($F(2,24)=77$, $p<.0001$), a result indicating spatial suppression. The strength of spatial suppression, however, did not differ between typical and ASD children ($F(2,24)=1$, $p=.38$). The unexpected result was better-than-normal motion discrimination in ASD ($F(1,24)=13.2$, $p=.001$). Specifically, across three stimulus sizes, we found a consistent two-fold decrease in thresholds for ASD observers. CONCLUSION: Given current theoretical models of ASD, our results reveal two counterintuitive findings. We find no abnormalities in spatial contextual modulations, but find a substantial and surprising enhancement in motion perception. What is the explanation? Our stimuli and task differ in two key ways from most studies that found motion deficits in ASD. First, we used simple (first-order) and highly visible motion stimuli, while deficits are typically found for complex moving displays (Bertone et al., 2003). Second, we used duration threshold measurements, which are effectively a measure of how quickly the visual system accumulates task-relevant stimulus information (Gold & Shadlen, 2000). One hypothesis is that ASD is associated with efficient accumulation of low-level motion information.

Acknowledgement: Autism Speaks Dennis Weatherstone Predoctoral Fellowship (JF), K01 MH090232 (CC), R01 EY019295 (DT)

63.442 Proportion of Cohort Population that May Benefit from Lasik

Adeline Yang[1](yhuixian@dso.org.sg), Sheng Tong Lin[1], Frederick Tey[1], Mellisa Tan[1], Gerard Nah[2]; [1]DSO Naitonal Laboratories, [2]Republic of Singapore Air Force

Introduction: To determine the proportion of military conscripts with ammetropia in this cohort study that may be suitable for Lasik corrective refractive intervention based on the success rate of using various machine to correct corneal refractive error. The parameters used for the evaluation are thickness of cornea and refraction of the sample population. Methods: 1,121 new male military conscripts aged 16 to 26 years with at least 1D of ammetropia were systematically selected from a population of 29,170 to undergo a Visante Anterior Segment Optical Coherence Tomography scan to determine their corneal curvature, thickness and anterior chamber depth. The stand-alone autorefractor, the Huvitz MRK-3100P machine was used to determine their refractive status. 4 models of machines were evaluated using their ablation table (Carl Zeiss Mel 80TM excimer laser, Zyoptix laser, VISX STAR S4 IR Excimer Laser System and Wavelight Allegretto Wave.) Results: It was found that 86.4% in our sample population are able to undergo Lasik successfully using Wavelight Allegretto Wave together with 130um femtosecond laser to create a flap. Our sample population represents 73.63% of the cohort population. As such, using the Wavelight Allegretto Wave may be able to correct 63.62% of the cohort population successfully. Conclusion: Despite the availability of the Lasik technology to correct for a wide range of refractive error, it is still dependant on the machine's ability to correct by ablating minimum amount of corneal tissue so as to correct for higher range of refractive error while accommodating thinner corneas.

63.443 Face Perception in School-Aged Children with Autism: A Look at Visual Processing Strategies

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Introduction: Atypical processing of face information has been associated with the social differences that characterize autism. One prominent hypothesis suggests that the unique, detail-oriented visual processing style used by autistic individuals may negatively affect their ability to identify faces when a global analysis is optimal, such as when faces are presented from different viewpoints. Assessing face identification abilities across ages and viewpoint is therefore important in understanding how and when differences in such abilities emerge between autism and typical development. The objective of the present study is to assess the face identity discrimination abilities of school-aged participants with and without autism in a view specific manner, where access to local face attributes is available (same view) or minimized (different views). Methods: Ten autistic and ten typically-developing school aged children matched for full-scale IQ and age (8 to 12 years) performed a two-alternative temporal forced choice, match to sample face identity discrimination task using synthetic, computer-generated face images (Wilson et al., 2002). Performance was measured using face identity discrimination thresholds for conditions where the target and choice faces were presented in the same view (front-front view) and in different views (front-side view). Results: Mean identity discrimination thresholds for the autistic group were higher for the viewpoint change condition (front-side view) when compared to the typically-developing group, which agrees with the findings from studies conducted in adults and adolescents with autism. No between-group differences were found for the same view condition. Conclusions: A decrease in performance for the viewpoint change condition, as indicated by higher mean identity discrimination thresholds, suggests that facial identity discrimination in school-aged children with autism may be more difficult when (i) access to local cues, such as individual facial features, is minimized, and/or (ii) increased dependence on a global, integrative analysis is introduced to the face task.

Acknowledgement: Canadian Institutes for Health Research- LM, AB

63.444 Global/Local Visual Processing in Autism: Not a Disability, but a Disinclination

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Integrating disparate information into a coherent percept is a key cognitive skill contributing to sensory processing, communication and social interaction. According to widespread claims, global attention is characteristically impaired in people with Autism Spectrum Disorder (ASD) and may be at the root of other aspects of the cognitive phenotype of autism. Although these claims are common in the literature, the empirical evidence is actually quite mixed. Here we ask i) do individuals with ASD in fact process local and global visual information differently from typical individuals, and ii) do performance differences between ASD and typical individuals reflect a difference in ability or preference? To address these questions, we tested participants in two experiments that used hierarchical shapes such as a triangle made of squares (Navon, 1983). In Experiment 1, we asked participants to categorize such hierarchical stimuli, but gave no indication whether each stimulus should be categorized at the local or global level. In Experiment 2, we measured participants' ability to process the same stimuli at either the local or the global level by instructing them to focus on either the global or the local level in different task blocks. Experiment 1 allowed us to measure the default inclination of participants whereas Experiment

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2 allowed us to measure the ability of participants when instructed. Here, we find that although children with autism show a stronger default preference to report local properties of a stimulus than do typically developing children when given a choice, their ability to process global properties when instructed to do so is unimpaired. These findings challenge prior claims that global processing is selectively impaired in autism and raise the broader question of whether other characteristics of autism may also reflect disinclinations rather than disabilities.

Acknowledgement: Ellison Medical Foundation, Simons Foundation

63.445 Contrast response functions for visual evoked nonlinearities demonstrate differences in magnocellular but not parvocellular components as a function of autistic tendency.

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Autistic tendency has often been associated with impaired visual motion sensitivity, global/local perception and visual discrimination of facial emotion. However, the neurophysiological mechanisms underlying this impaired visual perception have yet to be established. Nonlinear multifocal visual evoked potentials (Sutherland and Crewther, 2010) have demonstrated delayed magnocellular processing for high stimulus contrast in populations scoring high on Baron-Cohen's autism spectrum quotient (AQ). Here we investigated the contrast response functions of the main peaks of the first order and first two slices of the second order multifocal VEP with (central unstructured patch subtending 4°) with temporal contrasts of 10%, 25%, 50%, 70% and 96% in 29 normal participants (8 High AQ, 12 Middle AQ, 9 Low AQ) showing no group differences in non-verbal IQ (Raven's Advanced Progressive Matrices). Motion coherence sensitivity was also assessed. The contrast response function (CRF) for the first slice 2nd order (K2.1) showed high contrast gain and response saturation, while the second slice K2.2 showed lower contrast gain and little saturation – giving support for generation by the magno- and parvocellular systems respectively. As a function of participant AQ score, the High AQ group showed greater CRF amplitudes for the N60-P85 K2.1 response than Middle or Low AQ groups, while the CRFs for the N95-P125 K2.2 were similar across AQ groups. Tests of within-subject effects revealed a significant Contrast * AQ interaction between High and Low AQ groups. Also High AQ showed a significant delay in the K2.1 positivity at high contrast. An expected impairment in motion sensitivity was only observed in the High AQ group for limited lifetime low contrast (10%) coherent motion. The data suggest that the magnocellular system in High AQ individuals has more difficulty recovering after stimulation.

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63.446 Characterization of Optic Tract Degeneration in Patients with Damage to the Visual Pathway

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Trans-synaptic retrograde degeneration (TRG) in the optic tract (OT) has recently been demonstrated in patients with damage to the visual cortex. However, the time-course of this degeneration is unknown, as is the role of lesion extent on the severity of TRG. The current study used evidence from MRI structural images from patients with substantial visual field deficits to investigate the effect of lesion size and time since damage on OT degeneration. Fourteen patients with visual field deficits stemming from damage to the visual pathway were scanned, together with ten age-matched controls. OT size was measured from T1-weighted scans, by drawing a mask of each tract on a series of coronal images, and then computing OT volume at different voxel intensity thresholds. A laterality index (LI) was then computed for each subject to quantify the amount of degeneration present in the ipsilesional tract. Patients with occipital lobe resections showed the largest laterality indices, followed by those with damage to the tract itself. Patients with cortical lesions showed a highly significant correlation between LI and lesion extent. The LI in two patients with recent lesions did not differ significantly from controls. Degeneration over time was evident in four patients with recent damage who were each rescanned a year or more after the initial scan. Optic tract degeneration was present in all patients with long standing lesions, and severity of cortical loss was correlated significantly with the extent of atrophy. Repeated tests in patients with recent damage show increasing degeneration over time. This study shows conclusively that MRI can be used for monitoring retrograde degeneration in patients. Modulation of TRG may have a role in minimising collateral effects of brain damage and an understanding of the time course of the process is essential in the design of such a strategy.

Acknowledgement: MRC, Santander, Royal Society

63.447 Lack of visual experience does not affect the retinotopic organization of visual cortico-callosal connections.

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Purpose: The visual cortex in each hemisphere is linked to the opposite hemisphere by axonal projections that pass through the splenium of the corpus callosum. Recent human studies (Levin et al., 2010; Lepore et al. 2010) find that early postnatal blindness leads to reductions in splenium white matter volume; however it is not apparent whether these results reflect reductions in myelination and/or disorganization of splenial fibers. Here, using diffusion tractography, we examined the retinotopic organization of splenium connections within 6 anophthalmic and 6 control subjects. In anophthalmia, development of the eye is either absent or arrested at an early prenatal stage, and no functioning eye can be detected in the socket. Methods: Probabilistic diffusion tractography was performed on diffusion-weighted MR data (60 directions). Specifically, we tracked probabilistic fibers from seed points within the splenium to anatomically defined subregions that correspond in visually normal individuals to three eccentricity bands and the upper vs. lower visual field representations of early visual cortex (V1/V2). Each tractography seed point within the splenium was then labeled according to its connection probability to the V1/V2 retinotopic subregions in each hemisphere. This method has previously been shown to reliably identify retinotopic organization of fibers within the corpus callosum (Saenz and Fine, 2010). Results: We found that retinotopic mapping within the splenium was not measurably disrupted in anophthalmic subjects compared to visually normal controls. These results suggest that prenatal retinal activity and/or postnatal visual experience play little to no role in the organization of callosal connections within the splenium.

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63.448 Reduced LGN volume following early monocular deprivation from enucleation

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Background. The lateral geniculate nucleus (LGN) is a bilateral thalamic nucleus receiving information from each eye in separate layers. How is geniculate development affected when one eye is surgically removed (enucleation), consequently eliminating half of its retinal inputs? Animal models of eye enucleation suggest decreased LGN volume ipsilateral to the remaining eye in rabbits (Khan, 2005). Prenatal enucleation in monkeys is associated with a failure of layers to segregate, however, synaptic connections are formed between the remaining eye and neurons that would have otherwise been allocated to the enucleated eye (Rakic, 1981). LGN gray matter is decreased in humans following early monocular pattern deprivation from strabismus (Barnes et al., 2010). It is not known, however, how geniculate development is affected by monocular enucleation in humans. Methods. LGN volume of adults enucleated early in life due to retinoblastoma (cancer of the retina) was compared to that of binocularly intact controls. A series of 40 high-resolution proton density-weighted images were acquired with a 3T MRI scanner. Each series of scans were then registered and averaged. Raters used these averaged scans to manually identify and trace LGN regions of interest in each participant. Results. Individuals with monocular enucleation had a significant overall decrease in LGN volume compared to controls. However, this decrease was significantly less promi-

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nent in the hemisphere contralateral to the remaining eye. Conclusions. Our data suggest LGN cell degeneration due to the deafferentation of one half of visual inputs early in life. Further, the less pronounced decrease in LGN volume contralateral to the remaining eye suggests that the earlier developing crossed fibres may recruit some of the deafferented cells previously allocated to the enucleated eye.

63.449 **Staged gene therapy of canine retinal blindness does not produce cortical amblyopia for the later treated eye**

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Dark rearing of animals extends the window of ocular dominance cortical plasticity into adulthood, as demonstrated by the induction of amblyopia in an eye given brief monocular deprivation following reversal of dark rearing. In contrast to dark-rearing, binocular lid-suture does not produce this effect (GD Mower, Brain Res 1981). Is the visual deprivation of inherited retinal disease (specifically, RPE65-LCA) akin to dark-rearing or lid suture? This is clinically relevant as planned gene-therapy for this disorder is delivered by staged, monocular treatments, raising the possibility of therapy-induced amblyopia in the later treated eye. We studied four dogs with congenital blindness from RPE65 mutations. Two of the dogs ("staged") had one eye treated at 220 days of age. The second eye, and both eyes of the "simultaneous" dogs, were treated at day 320. MION fMRI during isoflurane anesthesia and monocular visual stimulation (5 Hz full-field luminance flicker) was collected at day 360, and again at day 420. Rod-cone b-wave amplitudes from ERG were also obtained. We tested for reduced amplitude of cortical response to the later treated eye in canine V1. Retinal gene-therapy produced roughly equal recovery of ERG responses in all animals, with the exception of a smaller response in the later treated eye of one staged animal. Gene-therapy for all 8 eyes restored cortical V1 responses to roughly half the amplitude seen in normal control animals. No reduction in amplitude to the later treated eye was observed. Variations in ERG responses did not account for any of the small variation in cortical responses seen. In conclusion, we did not observe evidence of treatment-induced amblyopia in the amplitude of cortical response, arguing against the equivalence of the visual deprivation from dark-rearing and RPE65-LCA blindness.

63.450 **Perceptual distortions in human amblyopia**

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Amblyopia is a developmental disorder of spatial vision, largely characterized by reduced monocular visual acuity and contrast sensitivity. These deficits are accompanied by supra-threshold perceptual distortions that have received much less empirical attention. Here, we examine these distortions in adult amblyopia using a novel, binocular space bisection task. Using red-green filters, we independently presented a probe and target stimulus to fellow and amblyopic eyes, respectively. The probe was randomly positioned at one of 32 positions (4 eccentricities x 8 axes); observers had to maintain central fixation (cross) and move the target from fixation to a position diametrically opposite the probe. The resulting maps of spatial distortions in 18 strabismic and 6 anisometropic amblyopic observers revealed errors in local binocular alignments (radial and tangential), which can be visualized as compressions, spatial offsets and expansions at all sampled locations. We identified distinct patterns of distortions across clinical subtypes of amblyopia. Maps from observers with anisometropic amblyopia were similar to normals, but showed increased positional variance. Global spatial offsets in the majority of strabismic maps corresponded with the angle of squint, whereas others revealed a pattern consistent with harmonious anomalous retinal correspondence. A small number of strabismic subjects showed unique compressions that were not easily explained by their clinical presentation. The magnitudes of error across eccentricities, when expressed in cortical units, yield an index of compromised cortical representation that differentiates between clinical groups. Overall, the task yields a rich quantitative characterization of perceptual anomalies in amblyopia, with potential for diagnostic applications in other visually impaired populations.

Acknowledgement: European Commission FP7 Programme

63.451 **Is there a physiological marker for the effects of perceptual learning in amblyopia?**

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Introduction Recently, there has been a resurgence of interest in the visual training of amblyopia via perceptual learning (PL) techniques. The purpose of this study was to record the physiological consequences of PL in amblyopia by simultaneously recording cortical oxyhaemoglobin (HbO) concentration using functional near-infrared spectroscopy (fNIRS). If PL reflects changes in neural activity/recruitment, it is possible that the behavioural recovery in binocular function may be reflected in an alteration in HbO levels as a result of training. There is also the possibility that the recovery of binocular function may show a unique physiological marker. Methods 2 adult subjects with amblyopia and 2 age matched controls undertook a dichoptic perceptual learning task for 5 sessions (each lasting one hour) over the course of a week. The training paradigm involved a simple computer game, which correlated the visual inputs and required the subject to use both eyes to perform the task. Measurements of HbO concentrations over the primary visual cortex at locations O1 and O2 were made during the training tasks using fNIRS. Results A significant difference in the mean visual acuity of the amblyopic eye was demonstrated pre and post training along with measurable stereo function being established. HbO levels were found to be consistently lower in amblyopic subjects than in normal subjects and to increase over the period of training for both amblyopic and normal subjects but with a faster rate of change in normal participants. Conclusion The dichoptic based learning therapy employed in the current study appeared to be effective in improving monocular visual acuity in the amblyopic eye as well as improving stereo function. Changes in HbO levels recorded throughout the period of training were concurrent with clinical improvements in visual function suggesting that cortical plasticity can be modulated over very short time-scales.

Acknowledgement: SW is supported by Hans Gertrude Hirsch Fight for Sight Award

63.452 **Long lasting contrast sensitivity improvement after daily cTBS sessions in adults with amblyopia.**

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There is increasing evidence of residual brain plasticity in adults well beyond the conventional critical period for visual development. Indeed, although traditional patching therapy to treat amblyopia is not effective above the age of 10 years, single session of 10Hz repetitive transcranial magnetic stimulation (rTMS) of the primary visual cortex in adults was shown to temporally improve visual performances (Thompson et al, Current Biology, 2008). We wanted to know whether continuous theta burst stimulation (cTBS) of the visual cortex could also be effective in restoring function in adult amblyopes and whether repeated daily application could result in stronger and longer-lasting effects. We tested 5 adult amblyopes (18-60 years). Contrast sensitivity was measured before and after cTBS using high (hSF) and low (lSF) spatial frequency stimuli. cTBS consisted in 600 pulses at 41% MSO intensity, delivered at 50Hz as bursts of 3 pulses repeated 5 times a second for 40 seconds on the visual cortex. Whereas no effect was observed on the contrast sensitivity of the fellow eye either at lSF or at hSF, or on the contrast sensitivity of the amblyopic eye at lSF, contrast sensitivity in the amblyopic eye at hSF improved, the effect becoming statically significant 30 min after the stimulation ($t4=3.59$, $p<0.05$). Four participants completed 5 successive days of that stimulation protocol and, as a group, showed a cumulative improvement across sessions with asymptotic recovery occurring after 2 daily sessions of stimulation ($chi^2 = 6.00$, $p<0.05$). We retested 3 subjects at various times after the final period of stimulation and found the functional recovery to remain stable over a period of up to 78 days. Having the advantage of being rapid to administer and using low intensities, cTBS appears well-suited for further investigation into the potentially beneficial effects of rTMS on visual function in adults with amblyopia.

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63.453 **Sparing of coarse stereopsis in children with amblyopia**

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It is widely recognized that stereoscopic depth percepts result from small retinal disparities within Panum's fusional area (fine stereopsis). Less recognized is the fact that reliable depth information is also provided by large disparities that cannot be fused (coarse stereopsis). The role of coarse stereopsis in vision is not well understood, but we hypothesize that it develops early in life and is used to guide vergence eye movements that are necessary for the development of fine stereopsis. This is supported by our recent finding that coarse stereopsis is mature by age 4 when fine stereopsis is still developing. Here we test the possibility that the early development of coarse stereopsis makes it resilient to the factors that cause amblyopia. We compared performance in children with strabismic or anisometropic amblyopia and age-matched control children (5-12 years) on computerized tests of fine and coarse stereopsis. Stereoscopic stimuli were presented using liquid crystal shutter glasses. The observer's task was to indicate whether a cartoon character was nearer or farther away than a zero-disparity fixation marker. We assessed perceived depth for a set of fine (0.02, 0.08, 0.17, 0.33, 0.67, 1.0 degrees) and a set of coarse (2.0, 2.5, 3.0, 3.5 degrees) crossed and uncrossed disparities. Accuracy increased with disparity in the fine range for both groups. Children with amblyopia performed significantly worse than control children at fine disparities, as predicted by their performance on the Randot Preschool Stereoacuity Test (>200 arc sec). Accuracy was constant at approximately 65% across all disparities in the coarse range for both groups. These findings suggest that coarse stereopsis may be spared when fine stereopsis is disrupted by early visual deprivation. This residual binocular function has important clinical implications, given the movement towards treating amblyopia as a disorder of binocular processing.

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63.454 Normal binocular rivalry in autism

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Evidence from animal models suggests that autism may be caused by an increased excitation/inhibition ratio in cortex (the E/I hypothesis). To test this hypothesis in humans, we measured behavior during binocular rivalry, a well-characterized visual phenomenon that depends critically on the balance between excitation and inhibition. In Experiment 1, we measured the duration of mixed percepts during observation of rival gratings in a sample of autistic adults and matched controls. Based on a computational model, the E/I hypothesis predicts longer mixed percept duration for the autistic population compared to the control population. Observers were shown sustained orthogonal gratings (-45/45 degrees) to the two eyes, and continuously reported whether they were perceiving the -45 degree grating, the 45 degree grating, or a mixture of the two. We found no evidence for a difference in mixed percept durations between the autistic and control populations. In Experiment 2, we investigated traveling wave speed. Traveling waves are a perceptual phenomenon in which the dominance of one percept emerges locally and then expands to overtake the other percept. The E/I hypothesis predicts faster traveling wave speeds in the autistic compared to the control population. Observers were shown a ring with high-contrast spiral bands in one eye, and another ring with low-contrast radial bands in the other eye. Using a brief contrast increment at the top of the radial ring, we induced a traveling wave of the radial pattern, and measured the speed by asking subjects to report the wave onset time at various locations. There was no evidence for a difference in the wave speed between the two populations. While our results do not falsify the E/I hypothesis, they suggest that an obvious E/I imbalance is not present in the visual cortex of autistic individuals.

63.455 Characterizing the Mechanisms behind Improvements in Visual Sensitivity during Childhood

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The human visual system is not an ideal transmitter of information. A number of separate, quantifiable factors, such as internal noise (Barlow, 1956; Pelli, 1981), have been introduced to characterize what limits our visual sensitivity and how it changes as a result of attention (Lu & Dosher, 1998), training/learning (Li & Levi, 2004), or aging (Betts, Sekuler, & Bennett, 2007). In the current study, we used external noise to model the mechanisms underlying improvements in sensitivity to contrast during childhood. We measured the contrast thresholds of 5-year-olds, 7-year-olds, 9-year-olds, and adults (n = 20/age) in a two-alternative forced-choice orientation discrimination task using the quick-TvC method that adaptively varies the contrast of the signal at a number of levels of external noise (Lesmes, Jeon, Lu, & Dosher, 2006). Overall, contrast thresholds decreased over a wide range of external noise levels as age increased (mean optimal contrast: 8.7%, 5.1%, 4%, and 3.3% for 5-year-olds, 7-year-olds, 9-year-olds, and adults, respectively). A perceptual template model based on Dosher and Lu (1999) provided an excellent fit (r2 = 0.985) to the developmental changes in contrast thresholds at different levels of external noise and performance. The model suggested that a mixture of mechanisms underlie the changes: the improvements in contrast thresholds across ages were best modelled by a combination of reductions in internal additive noise (Aa), reductions in internal multiplicative noise (Am), and improved external noise exclusion (Af). Between 5 and 7 years of age, there were 40%, 70%, and 45% reductions in Aa, Am, and Af, respectively. The modelled improvements likely reflect developmental changes at cortical levels, rather than changes of front-end structural properties (Kiorpes, Tang, Hawken, & Movshon, 2003).

Acknowledgement: Supported by CIHR grant # MOP 36430 and the James S. McDonnell Foundation

63.456 An Efficient Objective Measure of Binocular Suppression in Adult Amblyopia

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Binocular mechanisms affect monocular loss of visual function in amblyopia. Evidence of intact but suppressed binocular cortical mechanisms in adult amblyopes have been found in animal and human subjects. Binocular stimuli may therefore be more effective than monocular stimuli to treat suppression in adult amblyopes (Hess et al, 2010; Li et al, 2011). A measure of suppression is interocular contrast ratio (ICR), which estimates the relative signal strengths of the two eyes after combination (Hess). We tested a new, direct method to measure ICR using a protocol adapted from Mansouri et al (2008) in normally sighted and amblyopic subjects. Like Mansouri we used motion coherence displays, but we measured contrast thresholds at fixed motion coherence, rather than motion coherence thresholds at fixed contrast. The direction (up or down) of 12% coherently moving dots in random dot kinematograms was detectable when signal (coherent) dots had sufficient contrast. The signal dots and noise (random motion) dots were presented either to the same eye or dichoptically. Stimuli lasted 500ms. Noise dots had 0%, 10%, 20% or 30% contrast. A staircase procedure was used to measure contrast threshold for signal dot motion direction. Conditions were presented twice, the first being for practice. Sessions lasted 45 minutes. The contribution of the amblyopic eye became measurable as contrast in that eye increased. Threshold ratios (ICRs) were higher by a factor of 2 when signal dots were presented dichoptically to the dominant eye in amblyopic subjects as compared to normally sighted controls. This method was efficient and results are consistent with Mansouri et al. to quantify binocular suppression. This measure of ICR is convenient to use for binocular approaches to perceptual learning in the treatment of adult amblyopia.

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63.457 The Role of Dorsal Stream Development in Form and Motion Coherence and Object Recognition: The Childhood Challenge of Processing Transient Events

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The Magnocellular Advantage model of the visual system was used to investigate the impact of differential timing of the development of the dorsal and ventral visual streams in children in comparison to adults. Specifically, it was aimed to determine how attention to, and the processing of, form and motion coherence and object information differs across ages as dorsally-driven, bottom-up attention mechanisms mature. Typically developing Younger Children (4-7 yrs), Older Children (10-13 yrs) and Adults (18-30 yrs) (N = 110) completed custom computerised motion and form coherence tasks and an object recognition contrast-sensitivity task designed to provide a functional measure of dorsal/ventral pathway performance. Both abrupt and ramped contrast onset/offset conditions were used. Whilst both conditions required ventral stream related object processing, the abrupt task has previously been shown to be related to better dorsal stream functioning. Thus the difference between ramped and abrupt threshold scores was deemed to indicate an advantage in processing transient information. No difference between age groups was seen on the form coherence task, except for the easiest condition. A significant improvement in performance was seen between younger children and older groups on the motion coherence task. Adults performed better than children on the object recognition tasks, whilst older children showed greater performance in processing in abrupt versus ramped conditions, in comparison to younger children. These psychophysical findings provide further support for a delay in the maturation of the dorsal pathway, in comparison to the ventral pathway. Further, they demonstrate that there is a measureable effect of this difference in maturation on the ability of children to direct attention to the processing of transient information. This suggests that young children may rely more on ventral stream visual processing for the perception of transient events, compared with older children and adults who utilize the dorsal stream to direct transient attention.

63.458 **Using a Modified Shape Discrimination Task to Assess the Interaction Between Low- and Mid-Level Visual Processes as a Function of Development**

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Introduction: Most studies investigating visual development have assessed lower (local) and higher (global) levels of processing in isolation. It therefore remains unknown whether immature perception at one level affects processing in the other as a function of development. The objective of the present study was to assess the typical development of low- to mid-level visual processes by evaluating the discrimination of circular shapes (global) differing in local attributes: luminance and texture. Methods: Typically developing school-aged children (n = 11, 7-12 years olds), adolescents (n = 13, 13-17 years old) and adults (n = 13, 18-25 years old) were asked to discriminate a deformed circle (target) from a pure circle in a 2-ATFC using the method of constant stimuli; deformation thresholds were measured. Stimuli consisted of radial frequency patterns: circular contours with a varying number of bumps or deformations (radial frequencies (RFs) of 3, 5, and 10), which establishes the global shape. The amount of deformation is set by the amplitude or size of the bumps (dependent measure), and the patterns are defined by either luminance or texture (local information). Results: A 3-way mixed factorial analysis revealed a Group x Local Attribute interaction, demonstrating that for both luminance and texture patterns, the school-aged group performed significantly worse compared to adolescents and adults. No significant difference between adolescents and adults was identified. A Local Attribute x RF interaction was also demonstrated, with discrimination thresholds for luminance-defined patterns differing significantly across all RFs. Alternatively, for texture-defined patterns, discrimination thresholds did not differ for RFs of 5 and 10. Conclusions: These results suggest that the typical development of low- to mid-level visual processes is only influenced by the type of local attributes (luminance vs texture) and not by the number of RFs defining the contour. Overall, immature low-level visual processes can potentially affect higher-level perception.

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