

York University CVR & VISTA International Conference on Vision in the Real World June 13 – 16, 2017

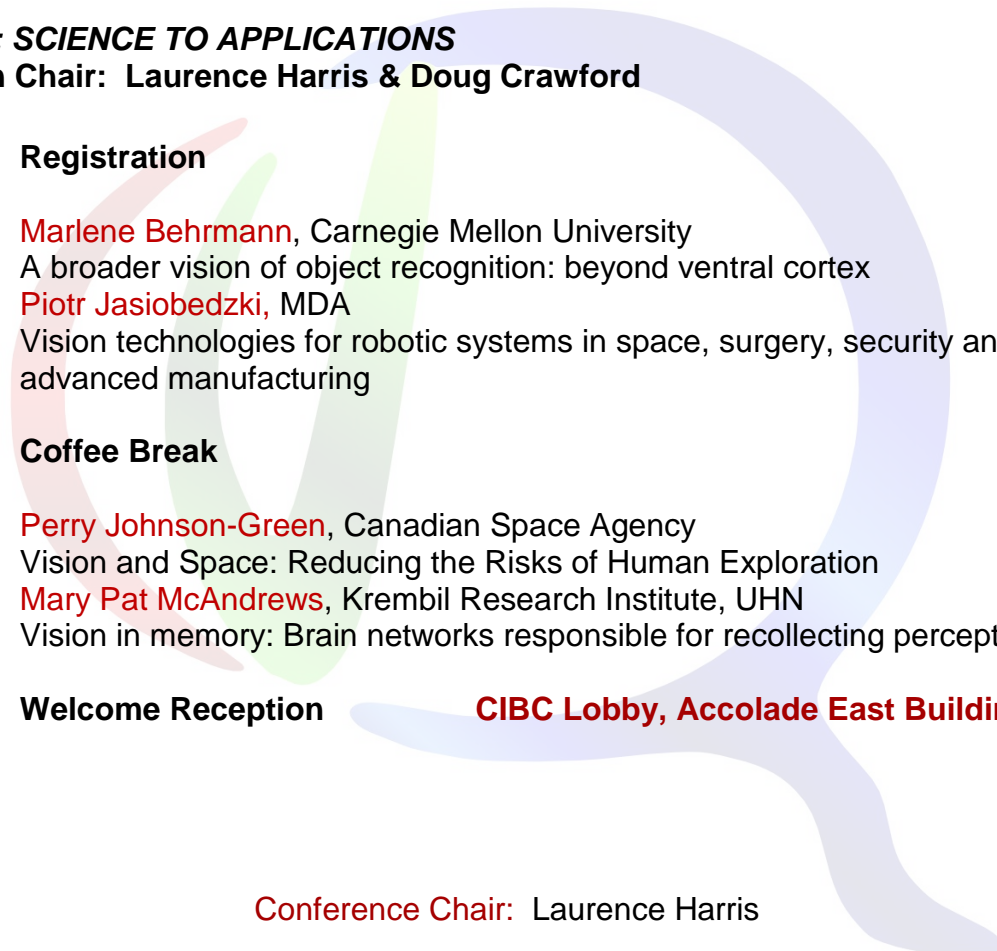
Recital Hall, Accolade East Building

Tuesday June 13rd

KEYNOTE SESSION

VISION: SCIENCE TO APPLICATIONS

Session Chair: Laurence Harris & Doug Crawford

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- 1:00 **Registration**
 - 2:30 **Marlene Behrmann**, Carnegie Mellon University
A broader vision of object recognition: beyond ventral cortex
 - 3:15 **Piotr Jasiobedzki**, MDA
Vision technologies for robotic systems in space, surgery, security and advanced manufacturing
 - 4:00 **Coffee Break**
 - 4:30 **Perry Johnson-Green**, Canadian Space Agency
Vision and Space: Reducing the Risks of Human Exploration
 - 5:15 **Mary Pat McAndrews**, Krembil Research Institute, UHN
Vision in memory: Brain networks responsible for recollecting perceptual detail
 - 6:00 **Welcome Reception** **CIBC Lobby, Accolade East Building**

Conference Chair: Laurence Harris

Wednesday June 14th

VISION AND LIMB CONTROL: MECHANISMS AND APPLICATIONS

Session Chair: Denise Henriques & Doug Crawford

8:00 **Continental Breakfast**

8:30 **Welcome**

8:45 **John Kalaska**, Université de Montréal
Neural Mechanisms of Action Selection in Dorsal Premotor Cortex

9:30 **Gunnar Blohm**, Queen's University
Towards understanding the statistics of visually-guided reaching

10:15 **Coffee Break**

10:45 **Lauren Sergio**, York University
Vision into action when faced with brain dysfunction

11:30 **José Santos-Victor**, Instituto Superior Técnico
Understanding Human Cognition with Humanoid Robots

12:15 **Lunch** (on your own)

VISUAL KNOWLEDGE: PRIORS AND LEARNING

Session Chair: Richard Murray

2:00 **Wilson Geisler**, The University of Texas at Austin
Multidimensional Normalization is Optimal for Identification in Natural Scenes

2:45 **Matthias Bethge**, The University of Tübingen
Visual abstraction in brains and machines

3:30 **Coffee Break**

4:00 **Tai-Sing Lee**, Carnegie Mellon University
Flexible encoding of natural scene priors in neural circuits

Free Evening

Thursday June 15th

NEURAL PROCESSING UNDER NATURAL CONDITIONS

Session Chair: Kari Hoffman & Thilo Womelsdorf

8:00 **Continental Breakfast**

8:45 **Mayank Mehta**, University of California, Los Angeles

From Virtual Reality to Reality: How Neurons Make Memorable Maps

9:30 **Dana Ballard**, The University of Texas at Austin

A model of fixation selection

10:15 **Poster Session & Coffee**

12:15 **Lunch** (on your own)

2:00 **Nachum Ulanovsky**, Weizmann Institute of Science

Neural codes for natural navigation in the hippocampal formation of bats

2:45 **Uri Hasson**, Princeton University

Hierarchical process memory: memory as an integral component of information processing

6:00 **Banquet**, Black Creek Pioneer Village

Friday June 16th

SEEING IN 3D

Session Chair: Rob Allison & Laurie Wilcox

8:00 **Continental Breakfast**

8:45 **Rob Allison**, York University

Perception in Stereoscopic 3D Media

9:30 **Marc Winterbottom**, Air force Research Lab, Ohio

Operational Based Vision Assessment Research: Aircrew Depth Perception Standards and Screening Methods

10:15 **Poster Session & Coffee**

12:15 **Lunch** (on your own)

2:00 **Jenny Read**, University of Newcastle

How insects see in 3D

2:45 **Andrew Parker**, University of Oxford

Searching for sites and neural correlates of cyclopean perception

3:30 **Closing Remarks**

3:45 **Wine & Cheese**

❖ INVITED SPEAKERS ❖

A broader vision of object recognition: beyond ventral cortex

Marlene Behrman
Carnegie Mellon University

The neural correlates of object recognition are typically assumed to be under the purview of the ventral pathway of the cortical visual system. Decades of empirical studies using neuroimaging and neuropsychological investigations, as well as single unit recording in awake behaving non-human primates, have supported this conclusion. I will describe some recent studies that examine the nature of these ventral neural representations including investigations that permit the reconstruction of the images displayed to the observer using previously acquired fMRI data from ventral cortex. I will then go on to argue that signals associated with object recognition extend beyond ventral cortex and that representations in the dorsal visual pathway and even in subcortical regions are tuned to represent shape and identity properties of objects. I will describe several studies using fMRI and psychophysics in both normal and brain-damaged individuals that support the role of these other regions in the recognition of visual objects. I will suggest that objects are widely represented in the brain and the challenge is to understand the necessity and sufficiency of these representations.

Vision technologies for robotic systems in space, surgery, security and advanced manufacturing

Piotr Jasiobedzki
MDA

MDA's advanced robotics & automation technologies span many diverse markets including space, medical, nuclear, security/defense and advanced manufacturing and are designed to work with the utmost precision, reliability and performance to meet the most stringent needs. The Company develops robotic solutions specifically for safety- and mission-critical applications that require a high degree of stability, accuracy, and dependability while operating beside, and with people.

MDA's sensors and vision systems aid in orbital rendezvous and proximity operations, while robotic arms capture resupply ships and perform servicing aboard the International Space Station. Unmanned robotics, automation systems and planetary science instruments are carried on international missions to Mars. Medical robots augment surgical teams with remarkable precision through less-invasive procedures. Nuclear robots designed for remote operation in dangerous environments protect people and exploit automation to improve workflows in a cost-effective manner.

Industrial automation creates superior operational solutions that address real-world needs safely, and dependably.

This talk focuses on solutions that rely on visual sensing to make decisions and perform autonomous actions, as well as, assist human operators in interpreting visual and multi-modal data. Selected recent and on-going projects are presented and specific challenges are outlined.

MDA solutions and products rely on advanced technologies and are often developed in collaboration with academic partners. Recent research collaboration models between MDA and academy are presented.

Vision and Space: Reducing the Risks of Human Exploration

Perry Johnson-Green
Canadian Space Agency / Government of Canada

Canadian astronauts have lived in space in the Space Shuttle and the International Space Station (ISS). They have also participated, along with their European, American, and Japanese colleagues, in human research, most of which has been aimed at better understanding the risks of human space flight. With regards to vision, research has focused on one specific issue –impaired vision because of deformation of the optical nerve, and a broader question –does weightlessness or reduced gravity affect neural processes related to vision? The ISS offers the opportunity to do vision research on a continuously inhabited spacecraft, with the potential of recruiting 6 participants per year from multicultural crews. The Canadian Space Agency periodically issues Announcements of Opportunity that allow Canadian scientists to submit proposals for vision research on the ISS.

Vision in memory: Brain networks responsible for recollecting perceptual detail

Mary Pat McAndrews
Krembil Research Institute, UHN

Some events can be recalled with rich perceptual detail, such that one can ‘re-experience’ them, and others are indistinct, with only the gist of the experience available. Considerable evidence suggests that the hippocampus (HC) plays a key role in recall of the former, particularly in how it interacts with posterior cortical regions including visual association cortex during retrieval. I will discuss evidence from studies of patients with hippocampal dysfunction and from functional neuroimaging studies of patients and healthy controls that demonstrates that interplay during recovery of perceptually vivid memories as well as characteristic interactions amongst regions when vivid recollection fails.

Neural Mechanisms of Action Selection in Dorsal Premotor Cortex

John Kalaska

Département de neurosciences, Université de Montréal

The arm and hand are the primary effectors by which primates interact with their environment and manipulate objects in the world. The cerebral cortical neural mechanisms for the sensorimotor control of reaching movements of the arm involve distributed motor circuits in the parietal, precentral and prefrontal cortex. These circuits extract salient sensory information from the world to select the appropriate reach actions to perform in the current behavioural context and to guide that action to successful completion. The dorsal premotor cortex (PMd) has been strongly implicated in many aspects of the sensorimotor control of arm movements, including the planning of different movement parameters such as reach direction, distance, speed, final target location and the reach trajectory, as well as the application of various rules by which actions are chosen from among several alternatives. I will review studies of the neural processes in PMd by which a simple colour-location matching rule is used to select the correct target from between two alternatives. I will show that the activity of an important population of PMd neurons appears to reflect the changing likelihood of different reach actions as salient sensory information becomes available while other PMd neurons are predominantly implicated in the preparation of the final chosen action. I will also describe the effects of different levels of ambiguity of salient sensory information on PMd neural activity and will provide experimental evidence that PMd is primarily implicated in the action-related aspects of the decision-making process required to select the correct target. In contrast, PMd activity does not strongly reflect the sensory/perceptual decision-making processes that are also required to apply the colour-location conjunction rule. Preliminary evidence suggests that the dorsolateral prefrontal cortex is strongly implicated the more sensory aspects of the application of the target-selection rule.

Towards understanding the statistics of visually-guided reaching

Gunnar Blohm

Centre for Neuroscience Studies, Queen's University

Systematic reach errors can be used to reveal neural processes underlying healthy and impaired brain function. But another aspect of reach error, variability, is often not analyzed and simply considered as noise. Here, I will show that changes in structure and magnitude of variability can reveal additional information about neural computations at play. In particular, changes in variability can be observed when the statistics of the visual environment or of the extra-retinal signals needed for motor planning and execution change. For example, signal-dependent noise in eye/head orientation signals impacts reach endpoint scatter. In addition, the distribution of reach endpoints is

distorted by stochastic reference frame transformations. Visual information also affects reach variability, as revealed by ego-centric / allo-centric integration experiments with different amounts of natural scene coherency. Most of these findings are consistent with optimal estimation theory stating that sensed signals should be interpreted as a function of reliability (=inverse of variance). However, I will also show a counter-example where visual-proprioceptive integration violates Bayes optimality in the strict sense. Our models describing the above-mentioned processes demonstrate that the relationship between sensory and motor variability can reveal mechanisms that might otherwise have been overlooked.

Vision into action when faced with brain dysfunction

Lauren Sergio
York University

Two prominent health issues facing society today are 1) the impact of dementing illness on the elderly and 2) the impact of concussion on young athletes and workers. Whether caused by trauma or degenerative disease, the effect of mild brain insult on one's functional abilities is not well understood. This talk will review my group's fundamental and applied research on eye-hand coordination, particularly when the spatial location of what you're seeing (the guiding visual information) is different from the spatial location of the limb acting on the visual information. I'll discuss our work to date which shows that "cognitive-motor integration", or tasks which rely on rules to plan a movement (such as "push the computer mouse forward to move the cursor upward"), is impaired in individuals with a history of concussion, those in the early stages of dementia, and even those who show no symptoms but are at risk for dementia. I will also review the current thinking on how different regions of the brain interact to control rule-based visually-guided behaviour, needed for healthy functioning in everyday life.

Understanding Human Cognition with Humanoid Robots

José Santos-Victor
Institute for Systems and Robotics
Instituto Superior Técnico, Lisbon, Portugal

In this talk, I will give an overview of recent research projects in my lab at the Institute for Systems and Robotics, IST-Lisbon. I will describe our recent results on using artificial vision and humanoid robotics to help understanding certain functions of the human brain. In our work, we model human behaviour in an interdisciplinary research involving computational neuroscience, developmental psychology, and engineering.

One aspect is related to neuro-physiology and the discovery of the mirror neurons which suggest that both action understanding and execution are performed by the same (motor) areas of the brain, possibly the root for non-verbal communication and

facilitating social learning amongst con-specific individuals. I will present a computational model inspired by these findings and that outperforms (classic) approaches in gesture recognition from video.

A second aspect corresponds to the developmental pathway that allows by human infants (or robots) to successively acquire new skills based on previously learned capabilities while managing the complexity of the body-senses-environment. The talk will focus on aspects of sensorimotor coordination, learning about affordances and social interaction.

During the talk, I will provide examples of the use of humanoid robots (with our first platform, Baltazar, the iCub, and our social robot Vizzy) as testbeds to study human cognition, learning and sensorimotor coordination, while offering engineers with new approaches to build artificial systems.

Multidimensional Normalization is Optimal for Identification in Natural Scenes

Wilson S. Geisler
University of Texas at Austin

A fundamental everyday visual task is to identify target objects within a background scene. Under natural conditions, both the properties of the background and the amplitude of the target (if present) are generally different on every occasion, creating high uncertainty. Using a novel approach based on constrained sampling from natural backgrounds, we show that a biologically-plausible, normalized matched-template observer can account for many aspects of human identification performance in natural backgrounds, under conditions of both low and high uncertainty. We argue that the rapid and local neural gain-control mechanisms in the early visual system, and the psychophysical laws of masking, are most likely the result of evolving a near optimal solution to identification in natural backgrounds under conditions of high uncertainty.

Visual abstraction in brains and machines

Matthias Bethge
The University of Tübingen

Abstraction is key to visual perception. It is necessary to generalize from individual experiences and to robustly cope with the indefinite amount of detail in the world. Peripheral vision, change blindness experiments or cubistic arts are just few of many examples that can highlight the role of abstraction in human vision. Also in the now ubiquitously used deep convolutional neural networks (CNNs) the representation of the input becomes more and more abstract along the processing hierarchy. To what extent are the principles of visual abstraction the same in humans and CNNs? This question

can be studied by testing how sensitive humans and different CNNs react to different types of image manipulations. I will present psychophysical and theoretical results on the effect of such image manipulations which highlight intriguing similarities but also important discrepancies in the process of visual abstraction.

Flexible encoding of natural scene priors in neural circuits

Tai Sing Lee

**Computer Science Department, Center for the Neural Basis of Cognition,
Carnegie Mellon University**

Perceptual interpretation is ambiguous based on local information alone. Resolution of local ambiguity requires integration of global contextual information. Such integration can be mediated by a set of horizontal connections in neural circuits that encode the visual knowledge or statistical priors on the co-occurrence of edge signals and surface signals in natural scenes. In this talk, I will first provide neurophysiological evidence that shows, in addition to the well-known edge association field among orientation-selective neurons, there exists a disparity association field among disparity-tuned neurons in the primary visual cortex. The functional connectivity associated with the edge and disparity association fields can be learned using a probabilistic graphical model from natural scene data. Our success in using graphical models to link the natural scene statistics to functional connectivity in V1 neural circuits suggests the relevance of this class of models for conceptualizing computation in the visual cortex. I will further show that these neural circuits are very malleable, resulting in very flexible and dynamic integration of the global contextual information in these circuits.

From Virtual Reality to Reality: How Neurons Make Memorable Maps

Mayank R. Mehta

**Keck center for Neurophysics, Departments of: Physics & Astronomy; Neurology,
Neurobiology, UCLA**

The hippocampus is responsible for learning and spatial mapping. How does the hippocampus turn sensory stimuli into mental maps of space and how do they guide navigation? Research in this area has been guided by the Cognitive Map theory, which posits the hippocampus turns visual landmark information into abstract spatial representations. However, when animals explore the real world, several other parameters, such as locomotion and olfaction, also influence neural responses and behavior. This makes it difficult to determine the mechanisms of cognitive mapping. Hence, we have developed a noninvasive virtual reality system for rodents where sensory and behavioral variables can be precisely manipulated. We measured neural responses from the cortico-hippocampal circuit while rats performed spatial tasks, such as purely visual, virtual navigation, similar to the Morris Water Maze. We developed computational techniques to decipher the emergent neural dynamics. This

revealed surprising results about how hippocampal neurons turn visual information into behaviorally relevant neural maps.

A model of fixation selection

Dana Ballard
The University of Texas at Austin

The sequential deployment of gaze to regions of interest is an integral part of human visual function. Owing to its central importance, decades of research have focused on predicting gaze locations, but there has been relatively little formal attempt to predict the temporal aspects of gaze deployment in natural multi-tasking situations. We approach this problem by decomposing complex visual behaviour into individual task modules that require independent sources of visual information for control, in order to model human gaze deployment on different task-relevant objects. We introduce a softmax barrier model for gaze selection that uses two key elements: a priority parameter that represents task importance per module, and noise estimates that allow modules to represent uncertainty about the state of task-relevant visual information. Comparisons with human gaze data gathered in a virtual driving environment show that the model closely approximates human performance.

Neural codes for natural navigation in the hippocampal formation of bats

Nachum Ulanovsky
Department of Neurobiology, Weizmann Institute of Science, Israel

The work in our lab focuses on understanding the neural basis of spatial memory and spatial cognition – using bats as our animal model. In my talk I will present some of our recent studies, which explored the following questions: (i) How does the brain represent positions and directions in 3D? A set of studies in bats revealed that 3D positions are represented isotropically. 3D head-directions are represented in toroidal, rather than spherical 3D coordinates – allowing the brain to solve the discontinuity and non-commutativity problems of 3D directions. (ii) How are navigational goals represented in the brain? I will describe a new kind of vectorial representation of spatial goals, which we discovered in the bat hippocampus. (iii) I will describe our very recent discovery of bat hippocampal neurons that represent the position of other bats (conspecifics). (iv) Finally, I will describe ongoing work towards elucidating hippocampal neural codes in realistic, kilometer-scale environments. Our long-term vision is to develop a "Natural Neuroscience" approach for studying the neural basis of behavior – tapping into the animal's natural behaviors in complex, large-scale, naturalistic settings.

Hierarchical process memory: memory as an integral component of information processing

**Uri Hasson
Princeton University**

Models of working memory commonly focus on how information is encoded into and retrieved from storage at specific moments. However, in real-life, past information is used continuously to process incoming information across multiple timescales. Considering single unit, electrocorticography, and functional imaging data, I will argue that (i) virtually all cortical circuits can accumulate information over time, and (ii) the timescales of accumulation vary hierarchically, from early sensory areas with short processing timescales (tens to hundreds of milliseconds) to higher-order areas with long processing timescales (many seconds to minutes). In this hierarchical systems perspective, memory is not restricted to a few localized stores, but is intrinsic to information processing that unfolds throughout the brain on multiple timescales.

Perception in Stereoscopic 3D Media

**Rob Allison
York University**

State-of-the-art stereoscopic displays and virtual reality systems offer the promise of new immersive experiences. They also pose significant perceptual human factors challenges. We have been studying the sensitivity and tolerance of viewers to the key parameters content makers use to produce stereoscopic 3D media. These parameters potentially affect both the perception of depth in a 3D scene, and our sense of motion through it. I will review progress toward understanding when and how these artistic decisions impact a viewer's perceptual experience.

Operational Based Vision Assessment Research: Aircrew Depth Perception Standards and Screening Methods

Marc Winterbottom¹, Charles Lloyd², James Gaska¹, Logan Williams¹, Steven Wright³, and Steven Hadley¹

¹Operational Based Vision Assessment Laboratory, Human Performance Branch, USAF School of Aerospace Medicine, Wright-Patterson AFB, OH, USA

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Due to concern that current U.S. Air Force depth perception standards and screening methods may not be adequate for accurately identifying aircrew medically fit to perform critical depth perception tasks during flight, the U.S. Air Force School of Aerospace

Medicine has launched a program of research to investigate depth perception vision standards and screening methods, specifically concerning non-pilot aircrew. The research presented here focuses on the importance of depth perception for two career fields - remote vision system air refueling operators (boom operators), and rotary wing flight engineers responsible for clearing the aircraft for landing. Although each career field is subject to the same depth perception standard, the results of this research showed that good stereo acuity may be more important for boom operators than for flight engineers. The results also indicated that new, computer-based vision tests (stereo acuity, fusion range, motion perception) were predictive of both simulated RVS refueling performance and reported discomfort with the use of the hyperstereoscopic displays, while USAF standard vision screening tests (Armed Forces Vision Tester stereo acuity, phoria measures) generally were not. For the simulated helicopter landing task the use of stereoscopic displays clearly improved performance involving depth judgments. However, an individual's stereo acuity was not predictive of performance. Binocular fusion range and motion perception were better predictors of performance than stereo acuity. Potential implications for medical vision standards and, in our view, the clear need to modernize vision screening methods are discussed.

How insects see in 3D

Jenny Read
University of Newcastle

Stereopsis was once believed to be the preserve of "higher" animals such as primates, but is now known to occur in many animals, including herbivores with lateral eyes, and even insects. In this talk, I'll present recent behavioural results from my lab regarding stereopsis in the only invertebrate currently known to possess stereopsis, the praying mantis. Despite having tiny brains of only one million neurons, these visual predators can outperform humans on some stereo psychophysics tasks. I'll argue that mantis stereopsis is fundamentally different from our own, and appears to work by matching up regions of each eye's visual field which are changing over time.

Searching for sites and neural correlates of cyclopean perception

Andrew J Parker
University of Oxford

The nervous system brings together the independent signals from the two eyes into a single representation of objects in the visual world around us. Helmholtz and Julesz termed this process 'cyclopean perception', referring to the mythical single-eyed giants (Cyclops) of classical Greece. I shall review recent progress towards identifying the neural sites and correlates of cyclopean perception, using data from single-neuron physiology in non-human primates and high-field MR imaging in human participants.

❖ POSTERS ❖

1. *Interaction among binocular disparity, motion parallax, and pictorial depth cues for perceiving large depth*

Daiki Aramaki, Yasuaki Tamada & Masayuki Sato, University of Kitakyushu

To examine the interaction among binocular disparity, motion parallax, and pictorial depth cues for perceiving large depth, we measured the amount of perceived depth from these cues. The test stimulus was a photograph of a corridor in the university building that is very familiar to all of the observers. It was presented on a 65-inch plasma display and subtended 84 deg by 54 deg at 80 cm viewing distance. Three balls were placed 1.6 m, 6.4 m, and 25.6 m behind the display respectively in the scene. The observer's task was to estimate the distances to the balls. One hundred fifty one photographs of the scene were taken in advance while the position of the camera was horizontally shifted within 15 cm area with 1 mm step. The images presented on the display were chosen according to the eye position of observer that was measured with infrared LEDs and sensors to introduce motion parallax. The anaglyph method was used to introduce binocular disparity. The results showed that estimated depth exclusively depended on the pictorial cues confirming that those play a crucial role for perceiving large depth.

2. *The coordination of eye, head and hand movement during reaching at a visual target in head unrestrained Rhesus monkeys*

Harbandhan Arora¹⁻³, Vishal Bharmuria^{1,2}, Xiaogang Yan¹⁻³, Hongying Wang¹⁻³, SaihongSun¹⁻³ & J. Douglas Crawford¹⁻⁶, ¹Center for Vision Research, ²Vision: Science to Applications Program, ³Canadian Action and Perception Network, ⁴Department of Biology, ⁵Neuroscience Graduate Diploma Program, ⁶Departments of Psychology and Kinesiology and Health Sciences, York University

Non-human primates have been used extensively as animal models for human eye-head-hand coordination during gaze shifts (in a 2-D plane), but the more natural condition of eye-head-hand coordination during a 3-D reach has not been studied in monkeys. Here we determined how the initial eye and hand position affect the relative timing and accuracy of the eye, hand and head movement when reaching for a target. Eye, head, and hand motion were recorded in two Rhesus monkeys using search coil and touch screen technology, respectively. Animals were seated in a customized 'chair' which allowed the head to move freely and the hand to reach in both depth and direction. Monkeys were trained to touch LED point on a horizontal bar at the waist level to control initial hand position. Monkeys were then required to fixate gaze for 400-800ms on a central target. Finally, this fixation light was extinguished (go signal) and animals were required to reach toward one of 15 targets in a 40° horizontal x 20° vertical (visual angle) array, with the free movement of their eyes and head. Similar task was also performed for making only gaze shifts towards the target. Animals performed reliably, at success rates often exceeding 90%. Preliminary behavior analysis shows the head movement in the similar direction as the eye when accompanied with an arm movement. Reaction time for saccade is longer than compared with the reaction saccade time in the reaching task. These data will be further quantified for complete spatiotemporal description in behaviors previously tested in humans, with the addition of neurophysiological recordings.

3. *The Influence of Spatiotemporal Structure on Recall Accuracy in Memory-Guided Saccade Sequences*
Sharmini Atputharaj¹⁻³; David C. Cappadocia^{1, 4}; J. Douglas Crawford¹⁻⁵, ¹Centre for Vision Research, ²Vision Science to Applications (VISTA), ³Departments of Biology, ⁴Kinesiology, ⁵Psychology, York University

Saccades have been used extensively as a tool to measure cognitive processes such as visual working memory. The goal of this study was to identify the effect of spatiotemporal structure on performance in memory-guided saccade sequences. In this study, six participants (ages 21-34) took part in a task where they were presented with a sequence of targets on a 5x5 LED display which encompassed 20° x 20° of visual space. Participants were told to fixate the central LED and memorize a sequence of 3-6 targets was presented elsewhere on the display. The spatiotemporal structure of this sequence could be either (1) structured (recognizable shape and spatiotemporal order), (2) semi-structured (recognizable shape with random temporal order) or (3) unstructured (random shape and random temporal order). Following presentation of this sequence and the offset of the fixation light, subjects were required to saccade toward the remembered spatiotemporal sequence of targets. A 3-way ANOVA showed the following significant main effects: 1) saccade errors were greatest for the unstructured condition, and least for the fully structured condition and 2) targets presented earlier in a sequence were recalled with higher accuracy than later targets. There were also interactions between spatiotemporal structure of the sequence and 1) set-size (with structure providing greater benefits for larger set sizes) and 2) presentation order (with structure providing more benefits for the early targets). Overall, these results show that visual working memory capacity is improved by the presence of spatiotemporal structure but that this interacts with other factors such as set size. Acknowledgements: Saihong Sun provided programming assistance. Funded By: Canadian Institutes for Health Research

4. *Sudden stimulus switching during an attentional task affects the single cell's firing rate: A study case for the selective tuning model of attention (ST)*

Oscar Javier Avella Gonzalez & John K. Tsotsos, Centre for Vision Research, York University

Computational models of visual attention have successfully explained relevant features of in-vivo firing rate recordings in primates during attentional tasks. Nevertheless, the suggested action mechanisms for attention don't necessarily explain the physiological dynamics observed in the neurons responsible for those computations. Here, we present an updated version of the Selective Tuning model neuron (ST-neuron model - Tsotsos et al., 1995) and characterize the dynamics of the model neuron within a simple simulated visual hierarchy. We studied potential interactions between units, and how those lead to specific firing rate patterns in a task-dependent fashion on the basis of simple assumptions that explain its biological plausibility. Using the model, we simulated the effect on a single unit of sudden stimuli switching during attentional tasks, considering a variety of experimental configurations. Our results show that attentional enhancement of single neuron's activity can be easily explained based on the suppressive effect of attention suggested by the ST model. On the other hand, we show that stimulus switching during attentional tasks produces transients on the firing rate, such as bump or troughs, whose shape and amplitude correlate to the stimulus' relevance for the neuron (selectivity), and may lead in addition, to less strong long-lasting effects such as rate adaptation.

5. *Transsaccadic Integration of Object Orientation for Grasp Planning: an fMRI study*

B. R. Baltaretu¹⁻³, S. Monaco^{1,4}, Jena Velji-Ibrahim^{1,6}, Gaelle N. Luabeya^{1,7} & J. D. Crawford^{1-3, 5}, ¹Centre for Vision Research, ²Vision: Science to Applications (VISTA) program, ³Department of Biology, and Neuroscience Graduate Diploma Program, York University ⁴Centre for Mind/Brain Science, University of Trento, ⁵Departments of Psychology, Kinesiology and Health Sciences, ⁶Department of Kinesiology, ⁷Department of Biology, York University

It has been shown that intraparietal cortex is involved in the spatial updating of reach locations (Batista et al. 1999; Medendorp et al., 2003), and that extrastriate and inferior parietal cortex are involved in the trans-saccadic perceptual integration object orientation (Dunkley et al. 2016). However, it is not known how changes in eye position and object orientation influence cortical activity during grasp planning. Here, we used an fMRI-adaptation-inspired paradigm to investigate if saccades produce modulations in cortical areas involved in orientation-specific grasp plans. In each trial, participants (n=13) were instructed to fixate an LED left or right of center. A central elongated object (oriented 0° or 135°) was illuminated at center, then participants either fixated or made a saccade to the opposite side, and then the object was re-presented at the same (Repeat) or different (Novel) orientation. After the second presentation, participants grasped the object. We analyzed the second illumination period to identify modulations of grasp plans are based on: 1) spatial/gaze parameters (Saccade > Fixation) and 2) orientation (Novel > Repeat). During grasp planning, saccades recruited: left lingual gyrus (LG), lunate sulcus, middle occipital gyrus, cuneus, posterior intraparietal sulcus (pIPS), and superior parietal lobule, right calcarine sulcus and cingulate gyrus, and bilateral transverse occipital sulcus (i.e., occipital place area, OPA), superior occipital gyrus, anterior precuneus. The orientation specific areas were right inferior temporal gyrus, middle temporal gyrus (MTG), inferior occipital gyrus (IOG), supramarginal gyrus, and post aIPS. To identify the areas that were modulated by both saccade and orientation changes, we took the conjunction between these two contrasts. Activation was found in bilateral superior parietal lobule, left pIPS, superior parieto-occipital cortex, OPA, precuneus, LG, lateral occipitotemporal gyrus, and medial occipitotemporal sulcus. These data suggest that saccades and orientation changes may interact at an early stage to update grasp plans.

6. *Comparison of spatial coding in single/multi-unit data simultaneously recorded from frontal eye fields and supplementary eye fields during head-unrestrained gaze shifts*

Vishal Bharmauria, Harbandhan Arora, Xiaogang Yan, Hongying Wang & John Douglas Crawford, Center for Vision Research, York University

The neural mechanisms of visual-motor transformations are yet not completely known. We investigated the visual-motor transformations by distinguishing the spatial codes embedded in the visual (V) and motor (M) responses of the single- and multi-unit activities of the frontal eye fields (FEF) and supplementary eye fields (SEF) in head unrestrained monkeys. Monkeys made centrifugal gaze shifts toward briefly presented targets (with an allocentric cue) distributed across neuronal receptive fields. A variable memory delay was provided between visual stimulation and the go signal for a gaze saccade. During the delay period, a visual mask was briefly presented while the cue was displaced by 8° in one of eight radial directions. Both monkeys show a 25% influence of the cue shift on gaze behavior (Li et al. 2017). Employing similar model-fitting as Sajad et al. (2015, 2016), the preliminary egocentric single-unit analysis revealed that the FEF visual (n=10) burst encodes the target in eye-centered coordinates (Te), whereas the motor (n=11) activity best describes the gaze relative to eye (Ge). Furthermore, the spatially tuned multiunit activities also exhibited similar encoding strategies for the V (n=9) and M (n=5) responses, suggesting that visual motor transformations for a target occur at local level within the cortex. Further analysis is targeted on testing the allocentric models, analysis of gain fields, spatial transformations during memory delay (Sajad et al.

2016) and the comparison of single- and multi-unit visual-motor transformations between the Frontal eye fields (FEF) and supplementary eye-fields (SEF).

7. Investigating the Functional Anatomy of Visual Awareness: A Multivariate fMRI Study

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The right hemisphere is dominant for spatial attention and visual awareness. For example, patients with spatial neglect after right-brain damage to ventral parietal, temporal, and/or ventral frontal areas ignore the left side of space and show pathological biases to the right. In contrast, healthy participants show complementary biases to the left, called pseudoneglect, such as in perceptual judgement tasks. Pseudoneglect has been previously proposed to be associated with dorsal regions, especially in parietal cortex, known to activate in tasks of visual exploration and attentional shifts. However, this might reflect a confound because perceptual judgement tasks might have required shifts of attention whereas control tasks might not. Therefore, here we used a “grating-scales task” (GST) that requires participants to make perceptual judgements about the high (GST-HI) or low spatial frequency components (GST-LO) of the same stimuli, where both tasks afford similar amount of attentional shifts, but only the GST-HI induces pseudoneglect. As expected, we found that participants exhibited pseudoneglect only during the GST-HI but not during the GST-LO. Imaging results showed that dorsal areas such as the intraparietal sulcus activated bilaterally. However, areas in inferior and medial frontal cortex as well as insular cortex activated more on the right side during the GST-HI. Our data suggest that pseudoneglect activates a network of areas in the right hemisphere associated with portions of the ventral attentional network. These areas are consistent with some of the lesion sites observed in patients with spatial neglect.

8. Road Segmentation based on the Fusion of Geometry and Appearance

Gong Cheng, Yiming Qian & James H. Elder, Centre for Vision Research, York University

We propose a novel road segmentation method based on the fusion of geometric and appearance cues. Modeling colour cues using Gaussian mixtures allows the fusion to be performed optimally within a Bayesian framework, avoiding ad hoc weights. To make the proposed method adapt to varying scene conditions, we apply the nearest-neighbour appearance model selection over a mixture model dictionary learned from the training data. Moreover, the problem of deciding the number of mixture components in each mixture model is solved by a novel cross-validation approach. Quantitative evaluation shows that the proposed road segmentation method significantly improves the segmentation accuracy compared with a state-of-the-art road segmentation method which uses geometric cues alone.

9. A New Test for Measuring Contrast Sensitivity Across the Lifespan

S. L. Cornick, J. Higgins, & J. R. Drover, Memorial University of Newfoundland

Contrast sensitivity (CS) is the most comprehensive measure of spatial vision. Although there are many tests of CS, most exhibit ceiling effects and/or floor when measuring both children and adults. To enable lifespan studies with a single test, we developed a CS test modeled on the Adams CS cards and the Teller Acuity cards (TACII). The new CS cards have a sine wave grating paired with a blank field of equal average luminance. The cards are arranged in spatial frequency (SFs) sets (0.75 – 12 cpd). Contrast ranges from 0.2% to 50% with an average step size of 0.15 logCS units. We tested 417 participants (range: 2.7 to 23.5 years) on grating acuity using the TACII cards, on optotype acuity using the HOTV test, and on CS at using the CS cards. To evaluate validity of the CS cards, spearman correlation coefficients were calculated to determine the relationship between CS scores at 6 and 12 cpd and scores on the TACII and the HOTV test.

Finally, participants were arranged in age bins and mean CS functions (CSFs) were inspected for the typical inverted U shape. The correlation between the CS cards and TACII was strong at both 6 cpd ($r=-0.64$, $p<0.0001$) and 12 cpd ($r=-0.65$, $p<0.0001$). Similarly, the correlation between CS cards and the HOTV was strong at both 6 cpd ($r=-0.54$, $p<0.0001$) and 12 cpd ($r=-0.56$, $p<0.0001$). Interestingly, these latter correlations are essentially identical to that of the HOTV and TACII ($r=-0.56$). All CSFs demonstrated the inverted U shape. These results suggest that the CS possess good reliability. Furthermore, the cards do not yield ceiling effects/floor effects of previous versions of the test. Thus, the CS cards are appropriate for testing participants across the lifespan.

10. Target presence affects the eye movement behaviour and kinematics of non-human primates in virtual navigation tasks

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As technology and scientific knowledge have advanced, the possibility and necessity of using virtual environments to run experiments has arrived, and the eye movements that are used to explore the environments need to be characterized. We trained two rhesus macaques to use a joystick to navigate in a virtual environment during a complex learning task and a foraging task. We analyzed gaze on screen behaviour and eye movement behaviours: saccades, fixations, and smooth pursuits. We also analysed the kinematics of saccades across the tasks and within periods of the Learning task. We found that gaze on screen as a function of the proportion of a trial changed based on whether there was a target currently in the environment. There was a median trial proportion of 47% when the subject was just navigating. When there were rewarded targets, the median gaze-on-screen was 80% and 91% for the Foraging and Learning tasks. For saccade kinematics, we calculated the main sequence by matching saccades on start location (<5 dva) and direction ($<10^\circ$) in bins of 3 dva amplitude. We ran repeated measures ANOVAs to test for differences and we fit a non-linear model to estimate the change in the main sequence. We did not find an effect of static vs dynamic phase of stimuli in the virtual environment. We did find that saccades were 7% faster when there were rewarded objects on the screen in virtual environments, and that the different levels of difficulty in our task did not alter the main sequence. There is likely an arousal change between simple virtual navigation and navigation towards a rewarded target, when the subject is more engaged in the task.

11. Statistical procedure for assessing the relative performance of codecs using the flicker paradigm

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The transmission of digital image content frequently involves some form of compression to reduce the demand and complexity of the communication medium. Image data is compressed via a codec, which removes information that is either redundant or largely imperceptible to reduce the bit-rate required to transmit the image to the target device. In so-called 'lossy' compression, data from the original image signal cannot be completely recovered upon decoding, which can produce perceptible artifacts or noise. Psychophysical methods exist to assess artefact perceptibility and subjective preference following compression. A current industry standard (ISO/IEC-29170-2 Annex B) specifies a two-alternative forced choice procedure to measure artefact visibility. In this protocol, two versions of the same image are presented side-by-side on a display. In one location, an original (reference) and compressed image are temporally interleaved, while in the other location the original is presented repeatedly. Detectable differences between the original and compressed images will appear as localized flicker and observers are asked to indicate which of the images appears to flicker. The recommended statistical procedures outlined in the standards document are descriptive and do not assess the relative performance between codecs.

Here, we describe a statistical procedure that can be used to evaluate the relative performance of different codecs based on the ISO/IEC protocol results.

12. Increased scene exploration does not enhance memory

Claudia Damiano & Dirk B. Walther, Department of Psychology, University of Toronto

Research has shown that eye movements are beneficial to the recognition of scenes. Specifically, we have previously shown that when eye movements are disallowed during the encoding of a scene, recognition accuracy falls to chance at test. This suggests that eye movements during the first viewing of a scene, used to visually explore and encode the scene, are critical for accurate subsequent memory. Here we probe the ability to enhance memory by, rather than restricting eye movements, encouraging people to explore the scene more thoroughly by making more eye movements during scene viewing. Fifteen participants viewed photographs of real-world scenes, followed by a new-old memory task. They were either allowed to look around the scene as they pleased (LOOK condition), or were instructed to make more eye movements throughout the scene (EXPLORE condition). An index of exploration behaviour was calculated as the root-mean-square-distance (RMSD) from initial fixation, weighted by fixation duration. Participants were able to follow instructions, in that their RMSD was significantly higher in the EXPLORE condition (5 degrees) than the LOOK condition (4.4 degrees, $p < .05$). However, recognition accuracy (hit rate) did not differ between conditions, meaning that the extra exploration did not have an influence on memory. These results, along with the results from our previous study, demonstrate that eye movements are necessary for proper encoding and thus accurate subsequent memory, however, once overt attention is already deployed, greater exploration within the same timeframe does not increase encoding efficiency. Therefore, the link between memory and scene exploration is likely a reflection of overt attention during encoding.

13. Full-body size perception in health adults depends on viewpoint

Sarah D'Amour & Laurence Harris, Centre for Vision Research, York University

Perceptual body size distortions have traditionally been studied in clinical populations using subjective, qualitative measures that assess only one type of body representation – the conscious body image. However, it is imperative to accurately determine baseline measures of how well healthy populations are able to judge their body size to understand how the body is implicitly represented in the brain. Here, we use a novel psychophysical method for determining perceived body size that taps into their implicit body representation. Participants were tested with the body presented in different viewpoints to see if performance changed for familiar and unfamiliar views. We expected that greater distortions would occur for the unfamiliar views. The Body Shape Questionnaire (Cooper et al., 1986) was also administered in order to determine if body dissatisfaction affects perceived size accuracy. Using a two-alternative forced choice (2AFC) design, participants were sequentially shown two life-size images of their full body seen from one of three viewpoints: front, side, or back. In one image, the aspect ratio (with the horizontal or vertical dimension fixed) was varied using an adaptive staircase, while the other was undistorted. Participants reported which image most closely matched their own body size. The staircase honed in on the distorted image that was equally likely to be judged as matching their perception as the accurate image. From this, their perceived size could be calculated. Participants were not accurate at judging their full body size and differences occurred depending on the viewpoint presented. These results provide psychophysically robust measurements of how accurately healthy participants perceive the size of their full body, revealing distortions of the implicit body representation independent of the conscious body image.

14. Bilateral vision loss in a case of acute annular outer retinopathy with invasive ductal breast carcinoma

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Purpose: Acute annular outer retinopathy (AAOR) is an uncommon disease. To date, there are few documented cases in the literature. Our study is the first to describe a case of acute annular outer retinopathy associated with invasive ductal breast carcinoma. Methods: Retrospective case report. Clinical examination and multimodal imaging including spectral domain optical coherence tomography and fundus autofluorescence were performed, and the findings are presented. Results: The patient presented with photopsias and visual loss approximately 4.5 weeks after diagnosis of invasive ductal breast carcinoma. We have documented the outer annular white ring seen in the acute phase of this disease and correlate it anatomically with SD-OCT imaging. We identified atrophy and nodular hyperreflectivity of the RPE and ellipsoid layer within the white annular ring with corresponding visual field loss. Fundus autofluorescence correlated with structural alterations seen on SD-OCT and showed both presumed active hyperautofluorescent zones with patchy hypoautofluorescent zones of atrophy and a classic annular hyperautofluorescent border. Our article provides additional information about the natural history of this rare entity and its prognosis and varied presentation. Conclusions: The authors report a single case of acute annular outer retinopathy with the corresponding SD-OCT, fundus autofluorescence and visual field findings, during the acute phase of the disease. These findings may help elucidate the possible causation for this rare disease.

15. Pattern-Based Functional Connectivity in Congenital Prosopagnosia

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Congenital prosopagnosia (CP) is the specific failure to recognize faces, in the absence of any known brain damage. One possible cause debated in the current literature concerns impaired connectivity within the face-processing network. In this study, we examine the relationship amongst seven regions of interest (ROI) identified in the bilateral posterior fusiform gyrus, bilateral anterior fusiform gyrus, bilateral inferior frontal gyrus, as well as the early visual cortex. More specifically, we investigate the relationship between pairs of ROIs using a novel version of pattern-based functional connectivity that aims to predict patterns of activation in one cortical region based on patterns of activation in another region. We argue that this methodology may be more sensitive to capturing subtle alterations in CP connectivity, relative to healthy individuals, than standard approaches of connectivity analysis. Overall, we find high levels of prediction accuracy across pairs of ROIs in both CP and healthy individuals. However, we also note lower levels of accuracy associated with fusiform and inferior frontal gyrus ROIs in CPs compared to healthy individuals. Concretely, we find that prediction accuracy between the right and left posterior fusiform gyri was markedly lower in one CP participant while, the accuracy between the right anterior fusiform gyrus and the right inferior frontal gyrus was lower in the remaining CP participants. Thus, we conclude that impaired connectivity may indeed be one underlying cause of face recognition deficits in CP while, methodologically we demonstrate the ability of pattern-based connectivity to shed light on the neural basis of visual impairments.

16. Discriminating depth edges in real-world scenes with 3D ground truth

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Luminance edges in an image are produced by diverse causes: change in depth, surface orientation, reflectance or illumination. Discriminating between these causes is a key step in visual processing. Previous work investigating edge discrimination in humans (e.g., Vilankar et al. 2014) has used small hand-labeled datasets which may be subject to bias. We use the new Southampton-York Natural Scenes (SYNS) 3D dataset (Adams et al. 2016) to build an objective ground truth dataset for depth versus non-depth edge classification. The SYNS dataset consists of spherical HDR imagery and LiDAR range data from randomly-selected outdoor and indoor locations. We used a standard computer vision edge detector to identify visible luminance edges in the HDR images and associated these with depth edges in the LiDAR range maps. We investigate the features which distinguish depth from non-depth edges in natural scenes. In line with previous work, we find that depth edges have higher contrast than non-depth edges. Colour, luminance, edge orientation, and elevation in the environment may also be used as cues to depth; all together, these cues allow us to classify depth from non-depth edges with 71% accuracy in outdoor scenes and 73% accuracy in indoor scenes. We also train various classifiers to discriminate depth from non-depth edges given a small image patch centred on the edge. We obtain the best performance from a convolutional neural network, which attains a classification accuracy of 85% in outdoor scenes and 81% in indoor scenes. In classifying outdoor edges, the network relies on both colour and edge orientation, but can attain an accuracy around 77% without these cues, probably by using texture, junction, and/or shape cues.

17. Background motion caused by self-motion does not cause motion-induced blindness

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The phenomenon of motion-induced blindness (MIB) is when salient targets tend to disappear when superimposed on a moving background. However, studies on MIB have been restricted to using small-field background motion. In realistic scenarios, full-field background motion is typically associated with self-motion in contrast to small-field background motion which is typically attributed to external motion. Visual motion resulting from self-motion is normally invisible; does it cause MIB? Participants sat in the York University Tumbling Room, a room that can rotate around the naso-occipital axis and in which the chair can also rotate around the same axis. Salient targets 2.8° from a fixation point were provided by three lasers attached to the chair. Participants viewed the display in full-field or in small-field-of-view (FOV $\pm 5^\circ$) created by wearing masked-down goggles. Participants fixated a central point during rotations of the room or the chair at 3rpm for 120s with or without the goggles and pressed a button when any of the targets disappeared. Results were compared to a no-movement condition as fixation can also cause targets to disappear (Troxler fading). Rotation of the tumbling room evoked vection 94% of the time during full-field viewing and 8% of the time with the goggles. MIB occurred when the participant was stationary viewing with a small-FOV. In all other cases, MIB beyond Troxler fading was not found. When participants attribute motion background as resulting from their own self-motion, regardless of whether the background motion is visually- or physically-caused, this seems to consume the background motion that generates MIB therefore attenuating the effect. This suggests that background motion caused by self-motion is removed from perceptual processing before the point at which MIB occurs.

18. Effect of Animacy on Ensemble Orientation Perception

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Our perception of the world appears to be rich and full of detail. However, the limitations of our visual system do not allow for a detailed representation of all the individual items that make up our surroundings. One method to overcome this is to represent groups of objects (i.e. ensemble) by extracting the statistical average of a shared property (e.g. the average direction of a flock of birds vs. the direction of any individual bird). Previous studies have found that ensemble averages are reported with greater accuracy than the properties of single items, and this is a robust effect that is seen across different visual properties (e.g. size, shape, colour). Most of the research that has been conducted in ensemble perception uses low-level stimuli. However, findings from recent studies suggest that high-level stimuli comprised of real-world objects challenge the notion of a fixed working memory capacity, and that ensemble processing also extends to high-level abstract dimensions such as animacy. The present study aims to determine if performance in an ensemble-orientation task is affected when comparing low (e.g. geometric shapes) and high-level (e.g. complex objects) stimuli, as well as animate and inanimate stimuli. Our findings suggest that there is no effect of high-level stimuli or animacy on ensemble orientation performance. However, performance on the ensemble-orientation task was consistently better than performance on the single-item orientation task. This suggests that the mechanisms mediating ensemble perception can robustly encode average orientation across a range of different types of stimuli.

19. Investigation Of Self-Orientation Under Varying Gravity States (SelfOG)

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Are gravity levels on other planets sufficient to provide adequate perception of “upright” for astronauts? Is the required gravity amount predictable from the physiological threshold for linear acceleration? Both gravity and visual information determine the perception of upright. In this project, we used a human centrifuge to simulate gravity levels from zero to earth gravity along the body’s long-axis and measured the subjects’ perception of upright using the Oriented Character Recognition Test with and without visual cues indicating a gravity direction that differed from the body’s long axis, allowing us to assess the relative contribution of the additional force to the perceptual upright. Control experiments off the centrifuge allowed us to measure the contributions of normal gravity, vision (visual effect) and body orientation. The influence of 1 g did not depend on whether the force was created by normal gravity or by lying on the centrifuge. The 50% threshold for centrifuge-simulated gravity’s ability to influence the perceptual upright was at around 0.15 g, close to moon gravity, but much higher than the threshold for detecting linear acceleration along the body’s long-axis. Results from earlier experiments indicated a discontinuity of the visual effect around 0.06 g. However, preliminary results from recent experiments focusing on the area around 0.06 g could not clearly confirm that discontinuity, suggesting that further research is necessary.

20. Commonalities Between Trans-saccadic Integration and Visual Working Memory

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The eyes make about three fast movements per second, and across these “saccades” the brain needs to update the spatial locations of objects to maintain a stable representation of the world. This is achieved through trans-saccadic integration involving processes of spatial remapping together with memory buffers. To understand how these processes relate to other cognitive mechanisms, in the current study we measured people’s trans-saccadic and other types of working memory performance. In the trans-saccadic task participants briefly viewed arrays of objects, followed by a saccade and then used a mouse cursor to click on one of the remembered object locations. In addition, they performed an n-back and a

change detection task, two well-established spatial visual working memory paradigms. We found that both classic measures were unrelated to systematic errors during the trans-saccadic task. However, unsystematic errors were predicted by n-back performance. Surprisingly, working memory capacity as quantified with change detection showed no correlations. Follow-up studies altered the change detection task in several ways to identify the features that would make it more similar to the other tasks. We ruled out features such as interference and remapping locations across visual fields. In contrast, forcing participants to detect changes based on egocentric rather than allocentric information did produce significant correlations. Our results suggest that trans-saccadic integration involves separate mechanisms for trans-saccadic remapping of spatial information and trans-saccadic memory. Moreover, trans-saccadic memory relies on similar buffers as other forms of working memory depending on the spatial coordinate system, with separate buffers for egocentric and allocentric representations of space.

21. Adaptive coding of spatial navigation and associative memory in primate hippocampus

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The hippocampus is critical for spatial navigation and associative memory across species. Hippocampal maps of space can change across behavioural states, but whether these changes are linked to new associative memories is unclear. We hypothesize that changing hippocampal representations of space are due to encoding of discrete, behaviorally relevant non-spatial, elements of associative memories. To address this, we recorded the activity of hippocampal neurons in two monkeys navigating a virtual maze during two different tasks: a foraging task requiring guided navigation, and a memory task requiring both navigation and context-object associations. Place fields of individual neurons were differentially distributed across the maze between tasks. During foraging they were homogeneously distributed, while during associative memory additional place fields clustered at the position of the task-relevant associations. The neural ensemble activity encoded a map of space in both tasks. However, coding was task-specific due to the emergence of neuronal tuning for discrete, task-relevant object features during associative memory. Thus, neuronal ensembles in primate hippocampus adaptively encode space and discrete elements of associative memories, providing a flexible common substrate for spatial maps and associative memories.

22. Evidence of Online and Offline Motor Control in Social Interaction: A visuomotor Joint Action Study

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Central to the mechanistic understanding of the human mind is to clarify how high level cognitions arise from simpler sensory and motor functions. A longstanding assumption is that forward models used by sensorimotor control to anticipate actions also serve to incorporate other people's actions and intentions, and give rise to core aspects of human social cognitions. To test whether forward models can be deliberately used to coordinate social interactions, here we measured the movements of pairs of participants in a novel joint action task. For the task they collaborated to lift an object, each of them using fingers of one hand to push against the object from opposite sides, just like a single person would use two hands to grasp the object bimanually. Perturbations of the object were applied randomly as they are known to impact grasp-specific movement components in common grasping tasks. We found that co-actors quickly learned to make grasp-like movements with grasp components that were coordinated offline based on action observation of peak deviation and velocity of their partner's trajectories. Our data suggest that co-actors adopted pre-existing bimanual grasp programs for their own body to use forward

models of their partner’s effectors. This confirms the idea that human cognitions have deliberate access to sensorimotor forward models to plan social behaviour.

23. Modulation Effects and Time Course of Target-Distractor Similarity on Saccade Curvatures

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According to the weighted average account, saccade curvatures are due to interactions between competing saccade vector representations in the oculomotor system. Given that the task relevance of visual stimuli is encoded in oculomotor neural substrates (Fecteau & Munoz, 2006), a prediction of the weighted average account is that saccade curvatures are functionally related to the level of cognitive activation/inhibition elicited by distractors. To examine this potential relationship, we created stimuli by conjoining individual line segments into holistic objects whereby the similarity between stimuli was manipulated by varying the number of individual line segments shared between stimuli. The relative similarity between two bilateral distractors and a target was systematically varied on a search task in which participants (N = 24) saccaded to the target. When distractors were equally similar, saccades deviated from baseline, $Z = -0.26$, $p = 0.798$; $Z = -0.15$, $p = 0.882$. When one distractor was more similar, saccades curved away from it, $Z = -3.11$, $p = 0.002$; $Z = -2.65$, $p = 0.008$, and this shift occurred during the first 60-80% of the length of the saccade, which corresponded to the first 23-31 ms. Saccade curvatures were also linearly related to relative similarity, $F(1,2) = 32.64$, $p = 0.029$, $R^2 = 0.94$; $F(1,2) = 44.92$, $p = 0.022$, $R^2 = 0.96$. As saccade trajectories were systematically biased away from the stimulus with higher target-similarity in a pair of spatially balanced stimuli, the current results suggested that a vector weighted-average computation performed prior to saccade initiation determined the final movement trajectory, consistent with neurophysiological models of vector encoding in critical oculomotor substrates. Critically, as computing target-similarity required a detailed analysis of shared features between objects, these results suggested that high-level object representations with associated features modulate the vector weights encoded by the oculomotor system.

24. Classification images for understanding lightness perception

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Lightness constancy is the ability to maintain a stable perception of surface lightness across lighting changes. Typical lightness experiments involve making perceptual matches or measuring thresholds (PSEs); here we measured classification images (Murray, 2011) to understand which image features contribute to lightness perception. Different theories of lightness perception emphasize different image features. Adelson (1993) emphasizes X-junctions (Beck, Prazdny & Ivry, 1984) for forming lighting boundaries; Shapiro and Lu (2011)’s high-pass filter emphasize isotropic surrounds; Blakeslee and McCourt’s (1999) oriented difference-of-Gaussians (ODOG) emphasize oriented filters. We expected classification images to discriminate between model predictions. We used the argyle illusion (Adelson, 1993) as our test stimulus. In this illusion, some patches appear lighter than others though they are of the same physical luminance. We chose this illusion because it is one of the strongest known lightness illusions and has also consistently resisted explanations by low-level models. We implemented three models: the high-pass filter model, the ODOG model, and an X-junction model (after Adelson, 1993). We measured PSEs and classification images for human and model observers. Human observers’ classification images showed a role of local contrast that depended on the lighting region shape (Gilchrist et al., 1999), which all models failed to show. Even the X-junction model failed, suggesting that X-junctions may help form

lighting boundaries but are not used to compute lightness. Overall, we found that classification images complement PSEs for understanding lightness perception, and our results demonstrate the importance of understanding lighting frameworks for developing a theory of lightness perception.

25. *How do Body Orientation and Optic Flow Affect Perceived Distance?*

John J-J Kim & Laurence R. Harris, York University

Visual-vestibular interaction is important in forming our perception of the world. The ability to judge egocentric distance – the distance between one’s own body and other objects – is a fundamental aspect of perception which is essential for our daily life. Any misperception in the distance perceived can be detrimental to the safety and the efficiency in our daily function. Despite the importance, past studies show our distance perception can be influenced by gravity, body orientation, and self-motion in ways that are little understood. We investigated how body orientation and self-motion affect the perceived distance of visual targets. 23 participants (12 females) judged the size of a visual target in virtual reality compared to reference length held in their hands in various conditions: upright (control), supine, and prone without optic flow, and upright with optic flow. During each condition, participants performed 25 trials, reporting whether the visual target rod was longer or shorter than the reference rod held in their hands. Perceived size was determined by fitting the participants’ responses to a logistic curve, from which the perceived distance was calculated. The results revealed (1) people perceived objects as 2.2% closer when supine and 5.8% closer when prone compared to when they were in an upright position, and (2) people perceived objects as 4.6% closer in the presence of optic flow (which would normally be generated by self-motion) than with the external world static. Our findings suggest distance perception is affected by both body orientation and self-motion, where we perceive objects as closer when lying down (regardless of the orientation) or moving compared to when standing upright and static. These unexpected results may be due to the survival benefit of perceiving objects as closer while in the vulnerable states of lying down or moving.

26. *Psychophysical response to virtual reality: Vection and postural sway*

Onoise G. Kio, Yoshitaka Fuji, Laurie M. Wilcox, Domenic Au & Robert S. Allison, York University

Stereoscopic 3D content can improve the quality of immersion and user interactivity in virtual and augmented reality. However, it is important to evaluate the behavioural responses to the content to assess its effectiveness. A typical psychophysical response is vection - the visually induced perception of self-motion elicited by a moving visual display. In this work we investigate how participants' postural sway in response to depictions of movement through a realistic virtual environment varies with the simulated optical flow speed and the virtual camera's framerate and exposure time. The degree of sway was interpreted from centre-of-pressure data obtained from a Nintendo Wii Balance Board. These data were compared with numerical vection ratings verbally reported by participants. Results obtained from this study show how vection experienced in virtual reality correlates with and influences the postural sway of users in various stereoscopic 3D movie settings.

27. *Determining the efficacy of locomotion interfaces in virtual environments using decision-making tasks*

Cyan Kuo, York University

Because vision works at a distance, pedestrians use visual information to plan a path towards a goal before setting foot on said ground. This behaviour is useful because troublesome terrain conditions can cause locomotion difficulties. Virtual environments can replicate the visual appearance of terrain conditions,

but the movements involved in using the interfaces confer their own bodily sensations possibly incongruent with visual conditions. Therefore, different locomotion interfaces, might differently affect navigation decisions such as the path to a goal. Here, I propose a method for examining the interaction of different locomotion interfaces with visual information and their effect on navigation decisions in virtual environments. For each trial in the experiment, participants will, using one of three locomotion interfaces, navigate towards a goal in a virtual room offering a choice of two paths to a goal. All locomotion interfaces will be tested for every path presentation. The paths will differ per trial in one of the following aspects (a) incline, (b) friction, (c) texture, and (d) width. The locomotion interfaces will be (a) joystick, (b) walking-in-place metaphors, (c) treadmill. Path condition, choice, time to goal, and locomotion interface will be recorded per trial.

28. Timing Object Perception with Stimulus-Mask Onset Asynchronies

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How long does neural information take to travel through the brain? Information might flow quickly because studies in monkeys show that neural responses in higher visual areas occur much earlier than 100 ms, suggesting that even top-down projections occur early on. In contrast, methods such as EEG report perceptual effects that occur around 100 ms and later. However, these times might include delays because EEG signals require synchronized postsynaptic potentials of larger populations of pyramidal cells and might not pick up faster processes. If so, stimulus-relevant sensory evidence and evidence accumulation for perceptual decisions should occur quickly, and should be affected by visual masks largely independently of visual noise succeeding a stimulus with different delays. To show this we used Monte Carlo simulations that modeled the extent to which stimulus signals were represented in the perceptual system to give rise to decisions about their presence or absence as a function of various stimulus-mask onset asynchronies (SMOAs) between 20 and 200 ms. We found that SMOAs had little effect on sensitivities in a “fast” version of this model whereas in a “slow” model, sensitivities rose monotonically with SMOAs. To confirm these findings, we asked human observers to perform an object detection task that trial-by-trial generated random objects out of line fragments embedded in arrays of distractor lines. Moreover, we masked the objects with different SMOAs like the model. As expected, sensitivities increased with SMOAs, consistent with the slow model. This supports the idea that perceptual processes occur at times visible to EEG.

29. Visual perception-imagery interaction: An investigation of shared neural systems using electroencephalography

Etienne Lefebvre & Derrick Matthew Buchanan, Neuroscience of Imagination, Cognition and Emotion Research lab (NICER), Carleton University

There is a long history in experimental psychology detailing how visual mental imagery can interfere with visual perception. However, little is known on the neural pathways underlying the visual perception-imagery interaction phenomenon. To identify preliminary neural correlates, we recorded event related potentials (ERPs) during a low-level perception visual acuity task. This task measured effects of interference or facilitation originating from two types of mental imagery. The low-level perception task required participants to detect the offset (left or right) of a line shaped stimulus from a fixation point while ERPs were being recorded from a 70-channel EEG Quick-cap. In the mental imagery conditions, participants were instructed to perform the perception task while generating an internal or external mental image of the line shaped stimulus at the centre of the fixation point. Behavioural results demonstrated that mental imagery prevented an interference effect; however no significant differences

were reported between a facilitation effect and the control condition. More interestingly, in the mental imagery conditions, ERPs in the frontal sites demonstrated stronger activity in the N100 and P200 waveforms compared to the control condition. These EEG-based findings, concurrent with the EEG-based findings of Ganis and Schendan's (2008) facial adaptation study, provide a preliminary account of the functional importance the frontal lobe plays in differentiating between the visual mental imagery and perception pathways.

30. Visual attention and reductionism: A cross-discipline analysis of variability within data

Etienne Lefebvre, Neuroscience of Imagination, Cognition and Emotion Research lab (NICER), Carleton University

To what degree is it justifiable to use reductionist methodologies to causally infer the biological mechanisms responsible for visual attention? An important indicator of a successful experimental reduction is a decrease or elimination of variability, compared to more holistic levels. For example, Kogan, Frankland, & Silva (2000) were able to eliminate the variability associated with social recognition memory at the behavioural level using a knock-out mice study. By knocking out a specific transcriptional factor they demonstrated that the knock-out mice were unable to recognize juvenile mice after a 24 hour delay period. Results such as this demonstrate that an effective and productive way to understand complex systems is to understand the system's component parts. However, some complex systems demonstrate non-linear/chaotic patterns, showing an increase in variability between the component parts and the outward system behaviour. These systems are immune to the methodologies of reductionism as variability tends to remain constant across levels of reduction. To investigate whether visual attention is best modeled using a linear or non-linear system, we analyzed over 90 academic papers encompassing five levels of reduction on the topic of visual attention. More specifically, we computed each paper's overall coefficient of variation to determine whether measures of variability remained constant or whether they decreased as a function of reduction. Our results demonstrated a significant linear decrease in variability from the brain region level to the genetic level. However, the most holistic level (psychology) and the most reductionist level (genetics) showed similar variability. These results could serve as a preliminary model to differentiate between emergent and reductionist components of visual attention.

31. Dorsal Modulations for Border Ownership Assignment

Paria Mehrani & John K. Tsotsos, York University

Experiments on the visual cortex show existence of border ownership (BOS) neurons in V1 and V2. The responses of these neurons not only depend on the orientation of borders, but also on which side of the border the figure is. Neurophysiological studies show that BOS cell responses depend on information outside the classical receptive fields. In other words, contextual information appears to be an important component for border ownership computations. Previous computational models suggested employing feedback modulations for border ownership neurons. The idea relies on the fact that neurons higher in the ventral stream have larger receptive fields and hence, can provide the required contextual information to BOS cells. In this study, we propose an alternative approach for this purpose: we propose that the neurons in the dorsal stream could provide the required contextual information for border ownership computation. In particular, we investigate the possibility of BOS cell modulations from MT neurons. The proposed model is currently under investigation.

32. Duration Dependency of Monocular Deprivation Induced Visual Plasticity

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Background: Short-term monocular deprivation has been recently shown to temporarily increase the sensitivity of the patched eye. Many studies have patched subjects for an arbitrary period of 2.5 hours, but for no principled reason. This project explores the duration-dependence of this deprivation-induced plasticity phenomenon. Methods: Three monocular deprivation durations were tested in nine subjects: 1-, 2- and 3-hours. Monocular deprivation was achieved by the use of a translucent eyepatch. A session included two rounds of baseline testing of interocular eye balance, patching, and post-patching tests, which are the abridged versions of the baseline testing. Each post-patching test occurred at 0, 3, 6, 12, 24, 48, 60 and 96 minutes after patching in order to track the effects over time. Every subject performed two sessions per condition. Results: 1-hour patching produced small but significant shifts in eye dominance. Larger shifts occurred from 2-hours patching, but 3-hours patching produced comparable effects to those measured after 2 hours of patching. Discussions: These results show a saturation of the patching effect beyond 2-hours patching. Hence, we believe that 2-hours patching duration is the optimal duration for eye dominance changes induced by monocular deprivation. Acknowledgements: We would like to acknowledge support from a CIHR project grant, an ERA-Neuron grant and an FRSQ Vision Reseau grant to RFH.

33. Shifts in predicted and perceived sensory consequences of hand motion are independent of explicit awareness of the task

Shanaathanan Modchalingam, Chad Vachon, Bernard Marius 't Hart & Denise Y.P. Henriques, Centre for Vision Research, York University

Explicit awareness of a task is often evoked during rehabilitation and sports training with the intention of accelerating learning and improving performance. However, the effects of awareness of perturbations on the resulting sensory and motor changes produced during motor learning are not well understood. Here, we use explicit instructions as well as large rotation sizes to generate awareness of the perturbation during a visuomotor rotation task and test the resulting changes in both perceived and predicted sensory consequences as well as implicit motor changes. We split participants into 4 groups which differ in both magnitude of the rotation (either 30° or 60°) during training, and whether they receive a strategy to counter the rotation or not. The effect of explicit instruction seems limited to an initial error-reduction advantage of ~20°, regardless of the size of the perturbation. We show that with instructions, and with large perturbations, participants are aware of countering the rotation. However, when asked to exclude the strategy, none of the groups are able to entirely, implying a base amount of implicit learning in all groups. Participants also estimate the location of the unseen hand when it is moved by the robot (passive localization) and when they generate their own movement (active localization). These estimates of felt hand position and predicted sensory consequences change independently of whether participants receive instructions or not. Our results indicate that not all processes of motor learning benefit from an explicit awareness of the task. Particularly, proprioceptive recalibration and the updating of predicted sensory consequences are largely implicit processes.

34. How do we count at a glance?

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Many studies have examined peoples' ability to rapidly perceive the approximate number of elements in a scene, but there has been much less work on what computation underlies this ability. We measured psychophysical decision spaces for number judgements.

Observers judged which of two stimuli contained more dots. The reference stimulus had fixed area and density on all trials. The test stimulus had a wide range of areas and densities across trials. From 3,300 trials we created a 2D plot showing the observer's probability of choosing the test stimulus as more numerous, as a function of its log area and log density. Fifteen such plots (five observers, three reference stimuli; 49,500 trials total) showed that number judgements were based on log-area plus log-density, i.e., they were monotonically related to true number (consistent with Cicchini et al., 2016).

We fitted a generalized additive model (GAM) to this data, and found that number judgements were based on almost perfectly logarithmic transformations of area and density, again demonstrating that number judgements are tightly linked to true number.

Finally, we ran adaptation experiments to test whether number adaptation is based on adaptation of number channels or density channels. Observers viewed an adaptation stimulus, followed by a test stimulus that had higher density but lower number. The perceived number of the test stimulus decreased after adaptation, consistent with number adaptation and inconsistent with density adaptation. We conclude that number adaptation is not mediated solely by density adaptation.

35. Multimodal facial image reconstruction: shape and surface-based models

D. Nemrodov, M. Niemeier, N. Drobotenko, A. Williams & A. Nestor, University of Toronto Scarborough

Reconstruction of image stimuli has been previously achieved with functional magnetic resonance imaging (fMRI) data as well as, more recently, with electroencephalography (EEG) data. However, a comparison of different modalities regarding their ability to support stimulus reconstruction along with their relative reliance on different classes of visual cues are yet to be explored. Here, we evaluate and compare the outcomes of facial image reconstruction based on fMRI, EEG and behavioral data. To this aim, we investigate the ability to reconstruct, from each modality, images of adult faces displaying different emotional expressions. Specifically, we aim to separately reconstruct face shape (i.e., a deformable configuration of fiducial points) and surface-based appearance (i.e., luminance and color properties of standardized 'shape-free' face morphs). Our results indicate that both shape and surface information can be recovered with above-chance accuracy from any of the modalities considered. However, surface is consistently retrieved with better accuracy than shape across all modalities. Interestingly, behavioral and fMRI-based reconstruction appear to perform equally well in terms of average accuracy, followed by their EEG counterpart. At the same time, EEG stands out by its ability to characterize the temporal dynamics of face encoding by supporting reconstruction for distinct time intervals. This investigation indicates that both shape and surface information can be recovered at multiple time points from the EEG signal and they are most effectively retrieved in the proximity of the N170 ERP component. Thus, our results speak to the feasibility and the relative success of stimulus reconstruction based on different data types while, theoretically, they shed light on the visual mechanisms for face recognition and their neural dynamics.

36. Why do LCD screens appear to glow?

Khushbu Patel, Leonard Palatnic & Richard Murray, York University

High-resolution LCD screens can depict realistic scenes, but even under restricted viewing conditions (e.g., monocular, stationary), we can usually tell that the surfaces and objects shown are not digital. One reason may be that we can tell the screen emits light instead of simply reflecting incident light. Here we investigated what cues allow observers to determine that a small patch of an LCD screen is light-emitting rather than reflective.

We cut a 3 x 3 grid of nine 3.2 cm square apertures in each of 27 black cardboard panels. Behind eight randomly selected apertures on each board we attached patches of gray and off-gray (e.g., beige) paper; we left the ninth aperture empty. The paper patches were picked randomly from twelve samples. On each trial, we put one board in front of a light-emitting LCD screen, and the observer judged which aperture contained the screen. In the luminance-match and colour-match conditions, the screen showed a gray region whose luminance or colour (i.e., CIE XYZ coordinates), respectively, were matched to a randomly chosen paper patch. In the luminance-texture-match and colour-texture-match conditions, the screen showed a luminance-calibrated and colour-calibrated photograph of a randomly chosen paper patch, respectively.

All observers (n=5) were well above chance performance in the luminance-match condition (83% correct), and luminance-texture-match (80%). Three were above chance in the color-match (20% correct) and colour-texture-match conditions (30%). We conclude that color is a driving cue for glow detection in this task.

37. MCMLSD: A Dynamic Programming Approach to Line Segment Detection

Emilio J. Almazan, Ron Tal, Yiming Qian & James H. Elder, York University

Prior approaches to line segment detection typically involve perceptual grouping in the image domain or global accumulation in the Hough domain. Here we propose a probabilistic algorithm that merges the advantages of both approaches. In a first stage lines are detected using a global probabilistic Hough approach. In the second stage each detected line is analyzed in the image domain to localize the line segments that generated the peak in the Hough map. By limiting search to a line, the distribution of segments over the sequence of points on the line can be modeled as a Markov chain, and a probabilistically optimal labelling can be computed exactly using a standard dynamic programming algorithm, in linear time. The Markov assumption also leads to an intuitive ranking method that uses the local marginal posterior probabilities to estimate the expected number of correctly labelled points on a segment. To assess the resulting Markov Chain Marginal Line Segment Detector (MCMLSD) we develop and apply a novel quantitative evaluation methodology that controls for under- and over-segmentation. Evaluation on the YorkUrbanDB dataset shows that the proposed MCMLSD method outperforms the state-of-the-art by a substantial margin.

38. Successful tracking of multiple 3D objects in the same or different depth planes depends on fixation position
Eugenie Roudaia

Maya Labrèche, Delphine Bernardin, Jocelyn Faubert & Aarlene Z Khan 1. School of Optometry, University of Montreal; 2. Essilor Canada Ltd.

The current study examined how separation of objects across different depth planes affects tracking performance under free- and fixed-viewing conditions. Stimuli were eight virtual tennis balls bouncing inside two virtual rectangular prisms placed one above the other, displayed with binocular disparity on a

large screen inside an immersive environment. Participants were required to track two of four balls in each zone. The speed of the balls was adjusted for each subject using a threshold procedure. In Experiment 1, 20 participants tracked targets located in two zones that were separated in depth by 0, 0.5, 1, or 1.5 m. Participants' eye movements were not restricted. Results showed no overall effect of depth separation. In Experiment 2, we restricted participants' eye movements and manipulated the depth plane of fixation and the separation in depth of tracking zones across four conditions. In two conditions, participants fixated in the near depth plane and tracking zones that were located either in the same depth plane as fixation or the top zone was at the same depth plane while the bottom zone was 1.5m further away (distal to fixation). In the other two conditions, fixation was far and the tracking zones were either both at the same depth plane as fixation, or the top zone was at the same plane while the bottom zone was 1.5 m closer (proximal to fixation). When tracking and fixating in the same depth plane, there was no difference in performance between the same-depth conditions, whether fixation was near or far. When the tracking zones were separated in depth, performance declined compared to the same-depth condition when fixation was close, but not when fixation was far. It appears that it is more challenging to attend to objects beyond the plane of fixation, as opposed to proximal to fixation.

39. Time course of adaptation and the error signals involved

Jennifer E. Ruttle^{1,2}, Bernard 't Hart¹ & Denise Y. P. Henriques¹⁻³, ¹Centre for Vision Research, ²Department of Psychology, ³School of Kinesiology and Health Science, York University

Reaching with altered visual feedback, a visuomotor rotation, leads to adaptation of internal motor plans, which results in aftereffects (deviated reaching without visual feedback) and proprioceptive recalibration, a shift in perceived hand location (Cressman & Henriques, 2010). The rate these motor and sensory changes arise is still being investigated. Zbib et al., 2016 found motor changes arise more quickly than proprioceptive changes, which required prolonged training to become significantly shifted. But their method is likely susceptible to decay of proprioceptive recalibration. Here we investigate the time course of these changes with a more sensitive method of proprioceptive assessment so that we are able to measure reach aftereffects and proprioception every 6 rotated cursor training trials. We employed two different training paradigms (classic and exposure) to investigate the specific contribution of cross-sensory error signals to the time course of learning. Classic training allows participants volitional control over movements. Whereas exposure training constrains participants' movements to a force channel, allowing only forward and back movements to the target location. The cursor always moves straight to the target, therefore eliminating motor errors. The hand was either abruptly deviated 30° or was gradually shifted 1° per trial until the hand was guided 30° CCW of the intended target (making the cursor rotation CW as per the previous study). Results show that motor adaptation and proprioceptive recalibration are of different magnitudes, but both occur in as few as 6 rotated-cursor training trials, regardless of training type experienced. The adaptation seen during exposure training suggests proprioception plays a major role in learning. These changes did not correlate with each other which suggest these processes are separate. Surprisingly, even the mere discrepancy between felt and seen hand location is enough to drive similar adaptation as seen following classic training.

40. Person Following Robot using Selected Online Ada-Boosting with Stereo Camera

Bao Xin Chen*, Raghavender Sahdev* & John K. Tsotsos, Department of Electrical Engineering and Computer Science and Centre for Vision Research, York University (* denotes equal contribution)

Person following behavior is an important task for social robots. It has many applications such as autonomous carts in grocery stores, personal guides in hospitals, or airports for autonomous suit-cases. Person following robots in dynamic environments need to address the tracking problem in real-time without critical failures. There are many situations where the robot will potentially lose tracking in a

dynamic environment, e.g., occlusion, illumination, pose-changes, etc. Past work used complex tracking algorithms to improve robustness. However, the trade-off is that their approaches may not be able to run in real-time on mobile robots. In this work, we present the Selected Online Ada-Boosting (SOAB) technique, a modified Online Ada-Boosting (OAB) tracking algorithm with integrated scene depth information obtained from a stereo camera which runs in real-time on a mobile robot. We build and share our results on the performance of our technique on a new stereo dataset for the task of person following. The dataset covers different challenging situations like squatting, partial and complete occlusion of the target being tracked, people wearing similar clothes, appearance changes, walking facing the front and back side of the person to the robot, and normal walking. A Proportional Integral Derivative (PID) based controller is used for the navigation behaviour of the robot. The velocity of the robot is proportional to the error in the target centroid from the center of the image and a pre-specified distance of the target (human) from the robot. More about the work can be found at <http://jtl.lassonde.yorku.ca/2017/02/person-following/>

41. Sensory Hypersensitivity and the Predictability of Repetitive Behaviours in Autism Spectrum Disorder

Samantha Schulz & Ryan Stevenson, Western University

Repetitive behaviours (RBs) are a core diagnostic symptom of Autism Spectrum Disorder (ASD) and tremendously impact an individual's day-to-day life. Recent work suggests that sensory sensitivity contributes to RBs in ASD. While these studies have provided evidence for a relationship between RBs and hypersensitivity, these studies have not identified if this relationship is specific to a particular sensory modality, nor included adequate control groups to test if this relationship is specific to ASD. The objectives of this study are to examine the relationship between hypersensitivity and repetitive behaviours across the sensory modalities and to determine if this relationship is specific to ASD. Parents of 114 children (ASD, n=49; TD, n=65) completed questionnaires reporting on sensory processing (Sensory Profile-2, SP-2), and RBs (Repetitive Behaviours Questionnaire-2, RBQ-2). T-tests confirmed exacerbated symptomatology in the ASD group, pushing them past the clinical threshold. Correlational analyses confirmed a strong relationship between the RBs and the Sensory Hypersensitivity in both ASD and TD groups and this relationship was consistent across the sensory modalities ($p < 0.001$). Finally, a hierarchical regression revealed that sensory sensitivities were predictive of RBs even when controlling for age, gender, intelligence, and diagnosis. These data provide evidence that hypersensitivity contributes to RBs overall and across the sensory modalities regardless of the presence of an ASD diagnosis.

42. Viewpoint Dependence in The Processing of Summary Identity from Face Ensembles

Sama M., Cant, JS. & Nestor A. Department of Psychology, University of Toronto Scarborough

When viewing an ensemble such as a crowd, it may be difficult to extract reliable information about any single individual. Instead, the visual system can extract a summary representation of the set, known as ensemble processing. Previous research has found that we can extract a viewpoint-invariant representation of summary facial identity and, conversely, we can also extract a summary viewpoint across different facial identities. However, a comparative evaluation of these processes and of their interaction, such as the accuracy of identity extraction across a wide range of viewpoints, still needs to be explored. In our first experiment, participants ($n = 15$) viewed an ensemble consisting of six faces that varied in either viewpoint or identity. They were instructed to report either the average viewpoint or identity of an ensemble, or the viewpoint/identity of a single randomly selected face. Results demonstrated that participants are equally accurate at extracting either average or single-face identity from face ensembles. In contrast, participants are significantly more accurate at extracting average viewpoint than the viewpoint of a single face. Further, a second experiment looked at sensitivity to

identity extraction across a range of viewpoints. Specifically, participants ($n = 8$) viewed face ensembles with average viewpoints that varied from 60° to the left or right relative to a frontal head orientation and reported average face identity. The results demonstrated that as the mean viewpoint of the ensemble departs from a frontal viewpoint, the accuracy of average identity extraction decreases. These findings speak to differential ensemble processing of lower versus higher-level visual information, illustrated here by viewpoint and facial identity. More generally, they serve to characterize the limits of ensemble processing and its dependence on different types of visual information.

43. *The luminance-depth gradient in 3D clutter: when does dark mean deep?*

Scaccia Milena, McGill University

Darker surfaces tend to appear further away but this cue can be easily overridden by other depth cues. Here we examine the dark-means-deep cue for foliage-like scenes which consist of thousands of small surface facets randomly distributed in a 3D volume. Under natural lighting, deeper surfaces in 3D clutter have lower luminance since deeper surfaces tend to be more shadowed. However, occlusion cues can override this dark-means-deep rule. Here we present an experiment that examines when the sign of the luminance-depth gradient in 3D clutter quantitatively affects the perceived depth of surfaces embedded in the clutter. We measured depth discrimination thresholds under monocular viewing of two target surfaces that were embedded in a 3D field of distractors i.e. clutter. We used two independent variables: the sign of the luminance-depth gradient, and the color saturations of the targets and distractors. We found that when the color saturations were the same, depth discrimination thresholds also were the same for positive and negative luminance gradients, and so the dark-means-deep rule was not used. However, when the color saturations differed, thresholds were elevated when brighter surfaces in the clutter were deeper, suggesting a dark-means-deep rule was used and worsened performance. To summarize, a luminance-depth gradient in 3D clutter has a greater influence on the perceived depth of targets if the targets and clutter have the same color. Possible applications in 3D visualization will be discussed.

44. *Attentional blink as a product of attentional control signals: A computational investigation*

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Although there are several different hypotheses regarding the origin of attentional blink, including interference, inhibition, and attentional capacity based explanations, largely, there have been few attempts to cohesively understand attentional blink from a single unified visual-attentive processing model. In the current work we have chosen Cognitive Programs model of visual processing (Tsotsos et al, 2014) in order to illustrate how attentional blink arises from executive control signals of visual-attentive module and visual working memory module. We have computationally simulated the rapid serial visual presentation (RSVP) tasks detailed in Raymond et al. (1992) using letters and oriented bars in order to capture important features of attentional blink. The novel aspect of our work is that in our work attentional blink arises as a by-product of visual processing and attentive control other than less parsimonious accounts of attentional blink.

45. *Where to Draw the Line: Effect of Artistic Expertise on Line Drawings of Natural Scenes*

Heping Sheng¹, Dirk B Walther^{1,2}, ¹Department of Human Biology, ²Department of Psychology, University of Toronto

Humans are able to quickly and accurately recognize scenes from line drawings. This suggests that contour lines are sufficient to capture important structural information from a scene. Indeed, previous work from

our lab has shown that viewing line drawings elicits similar neural activation patterns as viewing photographs, and that curvature and junction information is most helpful for human scene categorization. However, these results are based on line drawings made by one artist. In this study, we ask what contours and structural features are conserved across line drawings of scenes made by different people, and whether artistic expertise influences this consistency. We first developed software in Matlab Psychophysics Toolbox for tracing outlines over photographs of natural scenes (18 scenes, 6 categories) using a graphics tablet. Contours can be drawn free-hand or by creating a series of connected line segments. Spatial coordinates of the strokes are stored with temporal order information. We asked 43 participants with varying levels of artistic training to trace these photographs, and then extracted properties of contours (orientation, length, curvature) and contour junctions (types and angles) from each drawing. We found that curvature, orientation and junction types have the highest correlation between drawings of the same scene, across all scene categories, while contour length and junction angles are more variable between people. To characterize the contours that are most commonly agreed-upon, we match each drawing to a “super-reference” line drawing obtained via a separate rating experiment and a matching algorithm we developed in-house. We report that the most highly matched lines are typically drawn at the beginning of each trial, and aid participants in scene categorization, possibly due to global information conveyed through distinct contour features. However, we found no correlation between how well a drawing matched the super-reference and its subjective rating.

46. On temporal double-pulse resolution of color opponent pathways

Lin Shi, Kunming University of Science and Technology

Temporal characteristics of color opponent pathways were investigated by measurement of impulse response functions and temporal contrast sensitivity functions previously. Here, I studied the temporal double-pulse resolution of color opponent pathways. Firstly, positive and negative chromatic contrast detection thresholds of single-pulse detection at various background conditions were measured. Secondly, based on the previous measured detection thresholds, temporal double-pulse distinguishing inter-stimuli-interval (DPDISI) thresholds were measured. Chromatic coordinates of the background were sampled from 15 points in a cone chromaticity space proposed by Smith and Pokorny in 1996 which were corresponded respectively with the S/LM and the L/LM axes at following levels, S/LM: 0.8, 0.9, 1, 2, 3, and L/LM: 0.3, 0.335, 0.37. The stimulus was a Gaussian patch which chromatic coordinates were gradually changed from the peak to the background along one of the six directions, +S/LM, -S/LM, +L/LM, -L/LM, +LM, and -LM. The luminance of the peak was the same with the background except at +LM and -LM conditions which were luminance contrast cases. Results showed that the DPDISI thresholds of -S/LM were different from those of +S/LM, +L/LM, -L/LM, and +LM respectively which suggested unique temporal resolution of -S/LM among color opponent pathways. Acknowledgment: This study was supported by National Natural Science Foundation of China (61368005).

47. Subjective evaluation of image quality

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Advances in high-dynamic range, wide-colour-gamut displays have created unparalleled opportunities for improving image quality, but have also driven rapid expansion of data bandwidth requirements. To meet these needs, there is increasing demand for low-impairment display stream compression (DSC). The goal of low-impairment DSC is to ensure that the final product meets demanding compression targets, while being perceptually identical to the original image. Objective approaches, based on error metrics, are useful to a point, but cannot reliably predict the visibility of artefacts near the limits of detection. Thus,

subjective assessments are required to confirm that compression is visually lossless, a task that is made more complex by the fact that the benchmarks (e.g., what is visually lossless) are not well defined, and by a lack of theory linking these perceptual outcomes to objective error metrics. Subjective quality measures can be dramatically affected by choice of methodology, content and participant experience. Here we will discuss this issue in the context of our recent experiments in which we evaluated leading low impairment algorithms using a common image set, and a side-by-side flicker detection paradigm (ISO/IEC 29170-2). In follow-up trials we evaluated these same codecs using a modified motion-based paradigm and show that in this more realistic viewing scenario, viewers are often less sensitive to compression-related artefacts.

48. *The Influence of Stable Allocentric Cues on Transsaccadic Integration of Multiple Objects*

G. Tomou, X. Yan, & J. D. Crawford, Centre for Vision Research, York University

Transsaccadic integration is the ability to retain and synthesize visual information between different stable fixations. In order to do this, the brain must be able to retain and update object locations and features despite relative changes in retinal location produced by saccades several times per second. It is known that humans are able to retain several objects across saccades based on egocentric mechanisms, but it is not known what role allocentric landmarks play in this process. In order to test this, we compared performance in a transsaccadic integration task (e.g., Prime et al. Exp. Brain Res. 2007) with or without the presence of an allocentric landmark. 1-7 Gabor patches with pseudorandom orientations were presented on a frontal screen while participants fixated a randomized fixation cross. Following a visual mask, participants were required to saccade to a new location and were asked to identify whether a new Gabor patch presented at one of the same locations was rotated clockwise or counterclockwise from the original orientation. In 50% of the trials, an allocentric landmark (a stable cross positioned pseudorandomly within the stimulus array and extending across the screen) was presented throughout the trial. Preliminary results from 4 subjects confirmed the expected result that in the absence of the landmark, performance decreased significantly (from a baseline of ~90% correct) as the set size increased. More importantly, the presence of the landmark ameliorated this decrease in performance, providing a trend toward better performance for set sizes of 3 and higher. These preliminary results suggest that egocentric and allocentric mechanisms may combine to provide optimal performance in transsaccadic integration of multiple objects.

49. *AMAT: Medial Axis Transform for Natural Images*

Stavros Tsogkas, University of Toronto

The medial axis transform (MAT) is a powerful shape abstraction that has been successfully used in shape editing, matching and retrieval. Despite its long history, the MAT has not found widespread use in tasks involving natural images, due to the lack of a generalization that accommodates color and texture. In this paper we introduce Appearance-MAT (AMAT), by framing the MAT of natural images as a weighted geometric set cover problem. We make the following contributions: i) we extend previous medial point detection methods for color images, by associating each medial point with a local scale; ii) inspired by the invertibility property of the binary MAT, we also associate each medial point with a local encoding that allows us to invert the AMAT, reconstructing the input image; iii) we describe a clustering scheme that takes advantage of the additional scale and appearance information to group individual points into medial branches, providing a shape decomposition of the underlying image regions. In our experiments, we show state-of-the-art performance in medial point detection on Berkeley Medial AXes (BMAX500), a new dataset of medial axes based on the established BSDS500 database. We also measure the quality of reconstructed images from the same dataset, obtained by inverting their computed AMAT. Our approach

delivers significantly better reconstruction quality with respect to three baselines, using just 10% of the image pixels. Our code and annotations are publicly available in <https://github.com/tsogkas/amat>.

50. Motor Learning in Older Adults: Does Sensory Prediction and Explicit Processes Explain Differences in Performance on Visuomotor tasks?

Chad Vachon, York University

Our brains evolved to adapt our motor control to a variety of situations, including changes in our bodies, such as changed muscle strength or even trauma. Studies have shown aging can lead to a depreciation or maintenance in motor learning rates compared to younger adults because of a decrease in sensory and cognitive capacity, but it is unclear how older adults maintain task performance on some motor tasks and not others. Studies have not examined whether the differences in task performance are due to older adults relying more on efferent-based estimates of limb position than sensory-based ones. We examined whether cognition had an effect on task performance by informing both young and old adults of an explicit strategy to counteract a visual perturbation of their hand. We also compared how much young and old adults rely on prediction and proprioception when estimating hand position, before and after visuomotor adaptation. When given an explicit strategy, older adults had greater initial reaching errors than younger adults. Older adults had larger differences in their estimates of hand position compared with their felt hand position compared with younger adults. The results of this study provide insight into the factors that contribute to the differences in motor learning performance between young and older adults, and inform how we can best acquire new skills and rehabilitate after damage or deterioration.

51. Statistics of boundary, luminance, and pattern information predict occluding-target detection in natural backgrounds

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Detecting spatial patterns is a fundamental task solved by the human visual system. Two important constraints on detection performance are the variability that is found in natural scenes and the degradation of the image that occurs due to optical blurring and non-homogenous sampling of the retinal ganglion cell (RGC) mosaic across the visual field. Furthermore, most previous studies of detection performance have been conducted in the fovea with additive targets. However, image cues are different with occluding targets so these studies may not generalize well to occluding targets presented in the periphery. Here, we report eccentricity thresholds (eccentricity for 70% correct detection) for four different occluding targets presented in natural backgrounds at varying, but known, distances from the fovea. The luminance and contrast of the targets was fixed, and precise experimental control of the statistics (luminance, contrast and similarity) of the natural backgrounds was obtained using a novel method known as *constrained scene sampling* (Sebastian, Abrams & Geisler, accepted). Next, we describe a first-principles model, limited by known physiology of the human visual system and by the statistics of natural scenes, to compare with the pattern of observed thresholds. First, target-present and target-absent images are filtered by a modulation transfer function that approximates the optics of the human eye. Second, RGC responses are simulated by blurring and downsampling the optically-filtered image in a fashion consistent with the mid-range RGCs at each retinal eccentricity. The model then combines luminance, pattern, and boundary information in the target region to predict detectability across the visual field. We show that a weighted combination of these three cues predicts the pattern of thresholds observed in our experiment. These results provide a characterization of the information that the human visual system is likely to be using when detecting occluding objects in the periphery.

52. *The Perceptual Advantage of symmetry for scene perception*

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As one of the original Gestalt principles, symmetry is believed to support visual perception by aiding the visual system in detecting objects, which tend to be symmetric. Whereas the role of symmetry for the perception of isolated objects has been well studied, it is so far unknown what role symmetry plays in the perception of cluttered, real-world scenes. We demonstrate, for the first time, a strong perceptual advantage of local contour symmetry for perceiving complex real-world scenes. Unlike global symmetry, local symmetry is largely invariant to pose. Scenes were represented as line drawings, which have been shown to capture essential structural information required for successful scene categorization (Walther et al., 2011). We assessed local symmetry by computing the degree to which contour pixels participate in non-accidental symmetry relationships in the scene, using the medial axis transform (Blum, 1973; Siddiqi et al, 2008). Each contour pixel was assigned a numerical symmetry value based on the rate of change of the radius function of the medial branch to which it was assigned. We then generated two alternate versions of each line drawing, one with the half of the pixels ranked most symmetric and one with the half ranked least symmetric. The two types of modified line drawings were shown to twelve participants along with intact line drawings in a six-alternative forced-choice scene categorization experiment with short presentations (53 ms), followed by a perceptual mask. Each participant saw 20 images from each category, per condition (360 total trials). Participants' categorization accuracy was significantly higher for the most symmetric contours (49.7%) than for the least symmetric contours (38.2%), with intact contours showing higher performance than both modified conditions (65.8%). These results demonstrate, for the first time, the role of local contour symmetry as a crucial organizing principle in complex real-world scenes.

53. *Familiar vs Unfamiliar Facial Image Reconstruction from EEG Data*

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Elucidating the neural basis of facial identity recognition electroencephalography (EEG) has taken a new approach in recent years. While univariate analyses have helped to understand certain EEG markers associated with face processing, multivariate analyses are able to examine the data at a finer-grained level of detail and provide new insights into visual recognition. In the present study, we use pattern classification, feature selection and image reconstruction techniques to investigate spatiotemporal EEG patterns associated with viewing familiar and unfamiliar face stimuli. More specifically, we employed univariate analysis to identify traditional event-related potential (ERP) components. Then, we used pattern classification to discriminate between familiar and unfamiliar facial stimuli, followed by univariate feature selection to reduce the dimensionality of the patterns and to optimize classification performance. Finally, we adopted an image classification technique, originally designed for fMRI data, for the purpose of EEG-based facial image reconstruction. Our results show that: (i) familiar and unfamiliar faces can be discriminated well above chance; (ii) feature selection can efficiently eliminate around 90% of the data, and (iii) neutral and happy unfamiliar face stimuli can be successfully reconstructed from EEG data. More generally, we show that spatiotemporal EEG patterns contain a wealth of information regarding the nature of visual representations underlying face recognition.

54. Path Integration through Optic Flow: Effect of Reference Information in the Environment

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Classification of navigational strategy (allocentric vs egocentric) has been done through the use of optic flow tasks such as the Starfield task. Assignment depends on whether a person points back to origin in the direction of the original absolute heading (no egocentric heading update) or relative heading (updated heading for egocentric direction change). In Experiment 1, we analyzed participants' performance on the Starfield task as a function of their spatial abilities as measured on multiple standard spatial abilities scales. Error was taken as the difference between an individual's pointing direction to the relative heading homing vector. From this, classified 'allocentric' individuals underestimate pointing direction while 'egocentric' individuals exhibited a range of pointing encompassing both overestimation and underestimation around the true homing vector. We found allocentric individuals had comparable spatial abilities (ex. manipulating spatial knowledge, sense of direction...etc.) to egocentric individuals. This suggests categorization based on Starfield task performance inadequately captures allocentric strategy ability. If so-called allocentric navigators are better at employing global orientation cues, they should be more adept at integrating spatial information, benefitting from the addition of global landmarks. In Experiment 2, we applied a similar optic flow task in a largely open textured ground surface with or without the addition of stationary local or global landmarks as reference cues. We found classified allocentric individuals performed more poorly than other participants, and benefitted most from the addition of local rather than global landmarks. Combining results from experiments 1 and 2, our data are consistent with a growing body of evidence suggesting spatial orientation does not depend upon a single ability such as the use of egocentric or allocentric cues. Instead, optimal integration of multiple cues available is needed for successful navigation and orientation.

55. Pattern-Based Connectivity and Visual Recognition Invariance Within the Face-Processing Network

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The current study sought to explore the application of pattern-based analyses to the study of functional connectivity within the face-processing network. To this end we examined voxel-wise activation patterns in a set of face-processing regions of interest (ROI) as elicited by a face recognition task in healthy participants. Our investigation focused on 7 distinct ROIs identified in the bilateral posterior fusiform gyrus (FG), the bilateral anterior FG, the bilateral inferior frontal gyrus (IFG), as well as the early visual cortex. Specifically, we investigated the possibility of predicting patterns of activation associated with 60 different facial identities displaying 2 emotional expressions (neutral and happy) across pairs of ROIs. That is, we aimed to predict patterns of activation in one ROI from patterns of activation in another ROI using an L2 regularized regression model and a "leave-two-out" cross-validation procedure. Overall we have found highly significant levels of prediction accuracy across all pairs of ROIs considered with no difference for the two expressions or for prediction directionality (i.e., from posterior ROIs to anterior ROIs and vice versa). Further, we examined the possibility of predicting patterns associated with different expressions of the same facial identity- namely, we attempted to predict the patterns elicited from one emotional expression in one ROI from the patterns elicited by the other emotional expression in another ROI. This analysis revealed much smaller prediction accuracies across ROIs though significant levels of prediction were still detected in a few instances, especially as related to the bilateral IFG. Thus, the current work speaks to the validity and the utility of pattern-based approaches in the study of connectivity as shown here in the context of the face-processing network.

56. Feature-based surround suppression in the motion domain

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When we attend to a certain visual feature, other nearby features in that feature map are suppressed (feature-based surround suppression, Tsotsos, 2011). In the present study, we investigated feature-based surround suppression in motion direction, measuring motion repulsion under different attentional conditions (Marshak & Sekuler, 1979). A previous study reported that attention to one motion direction reduces motion repulsion by inhibiting the unattended direction (Chen et al., 2005). Based on this, we hypothesized that attention to one motion direction will reduce motion repulsion to a greater degree when two motion directions are similar to each other due to feature-based surround suppression. Motion repulsion is also affected by speed of motion (Curran & Benton, 2003). Thus, we varied speed of motion and examined the interactive effects between motion direction and speed on motion repulsion. Participants reported directions of two superimposed motions presented for 2 sec. Directional differences between the motions systematically varied (10~50 deg) and the motion surfaces were segregated by different colours (green or red). Speed of the motions was either 3 or 6 deg/sec. In the unattended condition, participants passively viewed both motions and reported their directions. In the attended condition, a colour cue indicated which motion surface should be attended. Participants were asked to detect a brief directional shift on the cued surface and then, report motion directions. Participants showed greater motion repulsion in the attended condition than in the unattended condition. However, the difference disappeared when two motions moved to similar directions, indicating feature-based surround suppression. Faster speed attenuated motion repulsion only in the unattended condition. It suggests top-down (feature-based surround suppression) and bottom-up (speed) factors independently influence motion repulsion.

57. Influence of sounds on eye gaze patterns during movie viewing

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Previous studies have found high inter-subject correlations (ISC; i.e., lower variability) in eye gaze patterns when viewers were presented with audio-visual stimuli such as an excerpt from the film “Bang! You’re Dead” (Hasson et al., 2008; Coutrot et al., 2014). This study aims to extend these findings and understand whether various types and contexts of sounds may differentially modulate similarities (or differences) in eye gaze patterns. Participants watched clips from six different movies, including the previously-used clip from “Bang! You’re Dead”. The clips were either presented with its original soundtrack, a soundtrack from the other movies, or with an ambient white-noise soundtrack. Additionally, the movie soundtracks were annotated to obtain detailed information such as what sound was heard (e.g., dialogue, gun shot) or when it was heard (timeframe). Currently, preliminary results suggest that the chosen movies (with their original soundtracks) may evoke similar eye gaze patterns, akin to the clip(s) used in other studies, and that viewers may explore the clips less when presented with the ambient white-noise soundtrack. Future analyses will examine 1) whether there will be high ISCs in eye position, fixation duration, and saccade amplitude in the original soundtrack conditions compared to the other soundtrack conditions; 2) whether fixation positions change over time and in the different soundtrack conditions by constructing sparse matrices; and 3) whether our annotations of the movies’ soundtracks can help explain changes to the matrices, so as to further understand the different influences of sounds on visual exploration. The results may further our understanding on how auditory information influences visual attention, as well as the degree in which it guides visual attention depending on its context.

58. Tolerance of Latency in Controlling a Quadcopter using a Head Mounted Display

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Recently, there is a growing interest in remotely piloting aerial vehicles, particularly quadcopters, using head motion tracked by a head mounted display. For example, tracked head orientation has been mapped to the attitude of a quadcopter for maneuvering it and first person views from the perspective of the quadcopter captured by onboard cameras have been presented onto the display panels of HMDs. A major difference between these head motion control methods and conventional control using a joystick is that, in the former case, head motion is coupled with visual updates. As the motion of a quadcopter is constrained by its dynamics, latency always exists between the issue of control commands by head movements and the feedback received at the completion of the attitude adjustment. This causes a discrepancy between the intended motion, the vestibular cue and the visual cue and may potentially result in simulator sickness. There is currently no research on how latency introduced by dynamics in head-controlled quadcopters affects users' flight performance and whether it causes simulator sickness. To address this issue, we present a virtual reality paradigm to experimentally control the degree of latency in simulated drone control scenarios and provide preliminary results from the experiment. We developed a quadcopter simulation application using WorldViz Vizard 5.0. This application allows a user to maneuver a quadcopter with head movements tracked by the Oculus Rift DK2. The step response of attitude adjustment of the quadcopter, corresponding to the latency introduced by dynamics, can be programmed by setting the gains in the quadcopter dynamics equations. The task for participants is to navigate the quadcopter through the waypoints placed in a virtual environment.

59. Neural Synchrony and Asynchrony as Mechanisms of Cortical Coding

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An animal running through patches of light and shadow generates a flickering pattern of contrast on an observer's retina. The flicker is locally synchronous amongst visual elements projecting from the same animal, but asynchronous between separate visual elements projecting from the animal and its environment. Thus, in the natural environment, elements that are part of a common object may be expected to flicker together, while elements that are parts of separate objects may be expected to flicker out of synch. Given only partial information about flicker, the visual system could fill in the missing information by propagating synchrony information via perceptual grouping cues. Synchrony has indeed been found to be influenced by grouping cues such as good continuation, proximity, similarity, and closure – modulating synchrony percepts by as much as 20°. Here we tested the effects of grouping by colour similarity on synchrony percepts and found the strongest effects reported yet, with perceptual phase shifts as high as 90°. Our simple experiment employed coloured dots on a grey background. On one side of the display, the dots were all the same colour, while on the other side they were split (top-to-bottom) into two separate colour patches. Flickering elements on the solid side were perceived to be much more synchronous than elements on the split side, thus demonstrating the efficacy of colour-based grouping cues on synchrony percepts.

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