



# SYMPOSIUM PROGRAM

SEPTEMBER 20, 2015

BRAIN AND MIND INSTITUTE | WESTERN UNIVERSITY



**Western**  
The Brain and  
Mind Institute



# WELCOME

## Welcome to the Inaugural Brain and Mind Institute Symposium (IBMIS)



The Brain and Mind Institute (BMI) is holding its first Symposium this year to highlight Western's multidisciplinary talent in cognitive neuroscience. This year is special. We are inviting our International Scientific Advisory Board to the BMI for the first time. The Board, which is composed of leading cognitive neuroscientists from around the world, will have an opportunity to meet our research team and see first-hand the range of cutting-edge research taking place at Western.

As the BMI continues to grow, we plan to make the Symposium a regular event, where the entire BMI community can come together to share, learn and celebrate our myriad of research activities. We also hope to eventually expand our invitations beyond the BMI group, to other members of the Western community, paving the way for future collaborative possibilities in cognitive neuroscience.

*-Melvyn Goodale (BMI Director)*

## Meet the International Scientific Advisory Board (ISAB)



**David Burr, PhD**  
*CNR Institute of Neuroscience  
Department of Psychology  
University of Florence  
Pisa, Italy*



**John Duncan, PhD**  
*Programme leader, Executive processes group  
MRC Cognition and Brain Sciences Unit  
Cambridge, United Kingdom*



**Alfonso Caramazza, PhD**  
*Daniel and Amy Starch Professor of Psychology  
Department of Psychology  
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*Director, Inserm-CEA Cognitive Neuroimaging Unit  
Collège de France  
Paris, France*



**Irene Tracey, PhD**  
*Nuffield Professor of Anaesthetic Science  
Director, Oxford Centre for fMRI  
University of Oxford  
Oxford, United Kingdom*

# SYMPOSIUM SCHEDULE

Time	Event	Location
8:30-9:00	Registration and Coffee	WSC 55
	Poster Setup	P&A Atrium
9:00-9:15	Welcome <i>Opening remarks from Dr. Melvyn Goodale, BMI Director</i>	WSC 55
9:15-12:00	Symposium Talks <i>Moderated by Dr. Jessica Grahn</i> <i>Presenters: Chris Fiacconi, Rae Gibson, Heather McGregor, Roberto Gulli, Molly Henry, James Hughes, Ian Lyons, Conor Wild</i>	
12:00-13:30	Lunch and Poster Session	P&A Atrium
13:30-15:00	Poster Session with ISAB	
15:00-16:00	Poster Session continued	
16:00-17:00	Poster Takedown and Break	
17:00-20:00	Evening Reception and Dinner	IGAB Atrium

*P&A = Physics and Astronomy Building; WSC = Western Science Centre; ISAB = International Scientific Advisory Board; IGAB = International & Graduate Affairs Building; Please refer to map on back of program for locations*



# SYMPOSIUM TALKS

WSC 55 | 9:15 AM – 12:00 PM

## **Detection of attentional and perceptual abilities in patients with Disorders of Consciousness using vibrotactile stimulation**

Raechelle M. Gibson (1)\*, Srivas Chennu (2), Adrian M. Owen (1), and Damian Cruse (1)

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Disorders of consciousness (DOC), such as the Vegetative State (VS) and Minimally Conscious State (MCS), are diagnosed on the basis of behavioural responses to external stimulation. Patients in the VS do not engage in any purposeful outward responses to commands. In contrast, patients diagnosed as in a MCS show some reproducible markers of awareness and responsiveness. We present a deviant detection paradigm that allows for a more detailed characterization of residual cognition in these patients using vibrotactile stimulation and electroencephalography. In a sample of sixteen patients, the presence or absence of the bottom-up attentional marker reliably distinguished between diagnostic groups. However, the marker of somatosensory perception was not related to any other available clinical measure. This paradigm is a valuable addition for a battery of neuroimaging-based assessments of residual cognition for patients with DOC. Such a battery will more thoroughly characterise the abilities of these patients and may even allow for two-way communication in some cases.

## **Finding Nonlinear Relationships in fMRI Time Series**

James Hughes (1)\*, Mark Daley (1)

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The brain is an intrinsically nonlinear system, yet the dominant methods used to generate network models of functional connectivity from fMRI data use linear measures (e.g., the Pearson product-moment coefficient). Although these approaches have been used successfully, they are limited in that they can find only linear relations within a system we know to be nonlinear.

This study employs a highly specialized version of a machine learning technique called genetic programming to perform symbolic regression, a type of regression analysis that searches for (potentially extremely complex) mathematical expressions to describe relationships between observed data.

Publicly available fMRI data from the Human Connectome Project was segmented into meaningful regions of interest and highly nonlinear mathematical expressions describing functional connectivity were generated with symbolic regression. These nonlinear expressions exceed the explanatory power of traditional linear models and allow for more accurate probing of the underlying physiological connectivities.

## **The Somatosensory System Supports Motor Learning by Observing**

Heather R. McGregor (1), Joshua G.A. Cashaback (1), Paul L. Gribble (1)\*

(1) *Western University, London, Ontario, CANADA*

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Motor learning involving physical practice results in sensory-motor cortical plasticity. Here we tested if the somatosensory system is also involved in motor learning by observing. In Experiment 1 we applied nerve stimulation to either arm while subjects observed a tutor performing a force field learning task using the right arm. Stimulation occupied somatosensory cortical processing with irrelevant input during observation. Stimulation delivered to the right arm (same arm used by the tutor) disrupted learning whereas stimulation delivered to the left (opposite) arm did not. This suggests that a somatosensory representation of the observed effector is necessary, and hence must be unoccupied, for motor learning by observing to occur. In Experiment 2 we assessed changes in primary somatosensory (S1) cortical processing following motor learning by observing by measuring somatosensory evoked potentials (SEPs). The N20-P25 component, which is generated by S1, increased in amplitude only in subjects who observed the tutor learning. Moreover, SEP increases were correlated with subjects' subsequent behavioural motor learning scores. These experiments demonstrate that the somatosensory system supports motor learning by observing.

## **The neural dynamics of sensing a beat**

Molly J. Henry (1)\*, Jessica Grahn (1)

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The ability to pick up on regularities in environmental stimuli is apparent in infancy and supports language learning, movement coordination, and parsing auditory scenes into “objects”. Humans are seemingly uniquely sensitive to temporal regularities in rhythm: they spontaneously feel a “beat” in rhythmic sequences. Perceiving a beat affords behavioural benefits, including better memory for and ability to discriminate between rhythms. Behavioural benefits and neural signatures of beat perception decrease with disorders like Parkinson’s disease. In the current talk, I will briefly describe the multi-modal and interdisciplinary approach the Music and Neuroscience Lab takes to uncovering the neural correlates of beat perception. I will focus on budding electroencephalographic (EEG) work investigating how synchronization of brain rhythms with auditory rhythms might give rise to beat perception. The work is rooted in EEG studies showing that brain rhythms periodically influence auditory perception, and patterns of performance modulation are predictable from the rhythmic structure of auditory rhythms with which brain rhythms are synchronized. In the context of beat perception, we contrast the behavior of brain rhythms in response to rhythms that either induce a strong sense of beat versus those do not in order to reveal the neural dynamics associated with beat perception.

## **Autonomic Contributions to Recognition Memory for Faces**

Chris M. Fiacconi (1)\*

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Many theoretical models of recognition memory posit that stimulus recognition can occur in the absence of explicitly retrieved contextual information surrounding the event in question (e.g., “butcher-on-the-bus” phenomenon). Typically referred to as familiarity-based recognition memory, this phenomenon is thought to be accompanied by a compelling subjective ‘feeling’ that an item or event has been previously encountered. However, it is at present unclear as to whether ‘feelings’ of familiarity share the same biological basis as other feeling states more traditionally defined. Guided by the framework that feelings result from the conscious perception of visceral bodily signals, we examined the extent to which ‘feelings’ of familiarity are shaped by feedback from the autonomic nervous system. Consistent with these ideas, we found that naturally occurring afferent cardiovascular feedback can enhance the subjective ‘feeling’ of familiarity, and that this enhancement may depend on inter-individual differences in perceptual sensitivity to this feedback. These results point to an important role for visceral feedback in guiding memory judgments, and suggest that ‘cognitive’ feelings may be grounded in the same machinery as other classically-defined feeling states.

## **Contextual learning in the monkey hippocampus during virtual navigation: From behaviour to single neurons**

Roberto A. Gulli (1,2)\*, Guillaume Doucet (1,2), Ben Corrigan (1,2), Sylvain Williams (1), Julio C. Martinez-Trujillo (2)

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The hippocampus is critical for contextual learning and memory, wherein disparate aspects of an experience are associated within a singular memory. However, the neural activity that underpins this complex cognitive function in primates is unclear. To address this, we created a virtual context-object associative memory task using a video game engine (Unreal Engine 3). Rhesus monkeys were trained to navigate through the virtual environment using a joystick and learn a context-dependent object-value hierarchy. Simultaneously, we recorded single neuron firing patterns and local field potentials from the hippocampus using transcranial electrodes. Immediately prior to monkeys viewing objects, hippocampal theta power was elevated and low gamma was depressed. However, as monkeys saccade between objects and navigate towards the chosen object, this trend is inverted. In ongoing analyses, we are exploring how single neuron firing patterns are modulated as animals learn context-object associations. In this talk, these results will be contrasted with existing rodent literature examining hippocampal activity during contextual memory.

## **Rich Auditory Representations in Cortex Even at 3 Months**

Conor J. Wild (1)\*, Annika C. Linke (1), Leire Zubiaurre-Elorza (1,2), Charlotte Herzmann (1,3), Hester Duffy (1), Victor K. Han (4), David S. C. Lee (4), Rhodri Cusack (1,4)

(1) *Western University, Brain and Mind Institute, London, Ontario, CANADA*

(2) *University of Deusto, Faculty of Psychology and Education, Bilbao, SPAIN*

(3) *University of Warwick, Department of Psychology, Coventry, UK*

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Despite tantalizing glimpses of neural responses to speech in very young brains, it is not known how the cortical representations of sound develop in the first year. Some models of perceptual learning emphasize the statistics of sounds, and suggest that common simple acoustic features (e.g., pitch) are learned first in order build up more complex sound representations, such as phonemes and words. Other models propose a top-down supervised process, whereby knowledge of complex sound representations is used to guide learning of simple features. To investigate how functional auditory development proceeds, we used functional magnetic resonance imaging to measure auditory responses evoked by sequences of sung lullabies in infants at 3- and 9-months of age. The songs evoked activity across an area of cortex similar to that seen in adults, and critically, we observed evidence of processing for complex and simple acoustic features even at 3 months. Furthermore, cortical auditory responses at 3 months were driven by a greater proportion of complex compared to simple auditory features, as compared to auditory responses in 9 month old. These results suggest that complex auditory processing emerges along with, or possibly before, low-level auditory processing, and are consistent with top-down models of auditory learning.

## **Are Numerals Numbers: Do number symbols operate like perceptual magnitudes?**

Ian M. Lyons (1)\*, Daniel Ansari (1)

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Number symbols – Indo-Arabic numerals – are relatively recent human inventions. Perceptual magnitudes – the number of berries on a bush – are processed similarly across many species. Are number symbols processed similarly to perceptual magnitudes – and hence might these magnitudes form the basis of symbolic number processing? A ubiquitous signature of perceptual magnitudes is that numerical ratio modulates neural and behavioural responses when comparing two magnitudes (8:9 is harder than 1:2). Here, we show that the ratio between two magnitudes predicts the similarity of those two magnitudes' neural activity patterns ( $R^2=.667$ ), but not for numerals ( $R^2=.017$ ). Moreover, the degree of similarity between a given pair of magnitudes was a negative predictor of the similarity between the same pair of numerals ( $r=-.366$ ,  $R^2=.134$ ). Next, we show that ratio is a significant predictor of response-times when comparing perceptual magnitudes for over 75% of 1,719 children in grades K-6, but only 30% of children when comparing numerals. Moreover, ratio-effects were unrelated ( $R^2=.011$ ). Both neural and behavioural data speak against the notion that number symbols operate – are modulated by ratio – like perceptual magnitudes. If numerals are numbers, they are perhaps a different kind of number. Future work might thus focus on properties unique to symbolic number systems.

# POSTER PRESENTATIONS (\*=corresponding author)

P&A Atrium | 12:00 PM – 4:00 PM

## 1. Eye-hand coordination in amputees

Lucilla Cardinali (1)\* & Tamar R. Makin (2), Jody C. Culham (1)

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Eye-hand coordination is a fundamental for interacting with the environment. Previous studies showed mutual influence of the eye and hand motor systems. Recently, Thura et al (2008) showed that saccadic reaction times (SRT) are modulated by whether a target appears close to or far from the participants' hand. To test the role of motor control in this effect, here we studied the modulation of SRT in individuals who lost or were born without hands. In three groups, one of acquired amputees, one of congenital amputees and one of age-matched controls we measured SRT to target appearing close to or far from 1) their intact/dominant hand, 2) phantom/non dominant hand and 3) prosthesis/grabber tool. We also introduced a baseline condition where no effector was present in the workspace. We found that in all groups the effector present as well as the congruency between the target and the effector position modulated the SRT. However, the type of modulation differed across groups. These results suggest that eye-hand coordination is modified by the absence or the loss of a limb. However, when a prosthesis or the dominant hand are brought into the amputated side the behavior changes suggesting that eye-hand coordination is a very dynamic process tightly linked to motor control.

## 2. Congruent Familiar Size Relationships Decrease Size Contrast Illusion

Maltseva, M.V. (1)\*, Stubbs, K.M. (1), Goodale, M.A. (1) & Culham, J.C. (1)

(1) *Brain and Mind Institute, Western University, London, Ontario, CANADA.*

We examined the effect of familiar size of objects on size perception. Participants matched the size of a target image to the perceived size of a central image in the Ebbinghaus illusion. The central image was identical throughout all trials (a 25-mm-wide dog), but the annuli varied in physical size (12 mm vs. 37 mm), semantic category (animate vs. inanimate), and familiar real-world size (cat vs. horse for the animate category; shoe vs. car for the inanimate category). Importantly, the familiar size relationship between the center and the annuli was either congruent (e.g., dog surrounded by *small* shoes or large cars) or incongruent (e.g., dog surrounded by *large* shoes or small cars). The strength of the illusion was weaker in the congruent conditions than the incongruent conditions for the inanimate category. For example, a dog of constant size was perceived as much smaller when surrounded by large shoes compared to small cars but the difference in perceived size was much attenuated for a dog surrounded by small shoes compared to large cars. These results show that perceived size is affected not just by the retinal size but also by familiar size relationships.

## 3. fMRI reveals different activation patterns for real objects vs. photographs of objects

Scott D. Squires (1)\*, Jacqueline C. Snow (1,2), Kevin M. Stubbs (1), & Jody C. Culham (1,3)

(1) *Brain and Mind Institute, University of Western Ontario, London, Ontario, Canada*

(2) *Department of Psychology, University of Nevada, Reno, Nevada, USA*

We used univariate subtraction and multivariate pattern (MVPA) analyses of fMRI responses to determine whether real world objects, and photos of the same items, are represented similarly in the human brain. Stimuli were presented in rapid succession in the scanner using a custom-designed conveyor belt. Participants viewed four exemplars (of different color, form, etc.) of one object type (e.g., whisks), in either real or photo format, in separate blocks. Univariate subtraction analysis revealed higher activation for real objects than photos in object-selective areas of the ventral stream, and dorsally in primary somatosensory cortex and anterior intraparietal sulcus. MVPA showed that early visual areas and lateral and ventral occipito-temporal cortex were sensitive to stimulus format. For example, whisks were more similar to whisks than to other objects, but real whisks were more similar to real whisks than photos of whisks. Our results indicate that the brain represents real objects and photos differently: real objects can invoke greater activation than photos, and representations of object identity are not identical between real objects and photos. Real objects might elicit different brain-based responses compared to photos because they provide richer visual information, have definite haptic qualities, and afford genuine action.

#### **4. Electrophysiological correlates of size constancy**

Juan Chen (1)\*, Irene Sperandio (2) and Melvyn A. Goodale (1)

(1) *The Brain and Mind Institute, the University of Western Ontario, London, Ontario, CANADA*

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Size constancy is the ability of the visual system to achieve a stable experience of perceived size despite the different viewing distances. To date, there has been little investigation of the neural mechanisms that underlie size constancy in a situation in which the real, rather than the apparent, distance (or size) of the stimulus is manipulated. In the present study, event-related potentials (ERPs) were measured to investigate the temporal dynamics of size-distance scaling. Filled black circles of two physical sizes were presented on a white background at two viewing distances. Participants were asked to maintain their gaze steadily on a fixation point throughout the experiment while EEG was recorded. We found that before 200 ms after stimulus onset, the ERPs of the two conditions in which the stimuli subtended the same retinal angle (i.e. 'small-near' vs. 'big-far') overlapped. The latency of the components before 200 ms decreased with the retinal size of the stimulus. After 200 ms, the ERPs of those conditions in which the stimuli were perceived to be the same size (i.e. 'small-near' and 'small-far'; 'big-near' and 'big-far') were synchronized. Our results suggest that size constancy was achieved no earlier than 200 ms after stimulus onset.

#### **5. Dissociating Action and Perception Using a 3D Variant of the Sanders Illusion While Controlling for Visual and Haptic Feedback**

Kate Merritt (1)\*, Robert Whitwell (1), Gavin Buckingham (2), Philippe Chouinard (1), Melvyn Goodale (1)

(1) *The Brain and Mind Institute, The University of Western Ontario, London, Ontario, CANADA*

(2) *Department of Psychology, School of Life Sciences, Heriot-Watt University, Edinburgh, UK*

According to the two visual systems hypothesis (TVSH), 'vision-for-action' and 'vision-for-perception' are mediated by two distinct cortical pathways. Supporting evidence for the TVSH has come from neuropsychological, neurophysiological, and neuroimaging studies of humans and non-human primates. One contentious line of evidence, however, comes from studies that find weaker effects of pictorial illusions on action than on perception. Re-appraisals of these studies have rendered the perception-action dissociation interpretation problematic, noting confounding task-differences in attention, stimulus-



response functions, obstacle avoidance, and visual and haptic feedback. Here, participants either reached out to pick up (length-wise) target bars embedded in the Sanders illusion or perceptually estimate their lengths. We removed visual feedback by suppressing the participants' vision throughout their grasps. We controlled for haptic feedback by allowing the participants the same opportunity to touch the targets in the perceptual estimation task as they had in the grasping task. In line with the TVSH, the illusory effect was significantly weaker on grasps than on perceptual estimates when the tasks were blocked separately and when the perceptual estimation and grasping tasks were alternated from trial to trial. These results provide positive evidence for separate visual-perceptual and visuomotor systems in neurologically-intact individuals.

## **6. The two-visual-systems hypothesis and the perspectival features of visual experience**

Robert T. Foley (1,2,3)\*, Robert L. Whitwell (4), Melvyn A. Goodale (3,5,6)

(1) *Rotman Institute of Philosophy, The University of Western Ontario, London, Ontario, CANADA*

(2) *Department of Philosophy, The University of Western Ontario, London, Ontario, CANADA*

(3) *Brain and Mind Institute, The University of Western Ontario, London, Ontario, CANADA*

(4) *Department of Psychology, The University of British Columbia, CANADA*

(5) *Department of Psychology, The University of Western Ontario, London, Ontario, CANADA*

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Some critics of the two-visual-systems hypothesis (TVSH) argue that it is incompatible with the fundamentally egocentric nature of visual experience (what we call the 'perspectival intuition'). The TVSH proposes that the ventral stream, which delivers up our visual experience of the world, works in an allocentric frame of reference, whereas the dorsal stream, which mediates the visual control of action, uses egocentric frames of reference. Given that the TVSH is also committed to the claim that dorsal-stream processing does not contribute to the contents of visual experience, it has been argued that the TVSH cannot account for the egocentric features of our visual experience. This argument, however, rests on a misunderstanding about how the operations mediating action and the operations mediating perception are specified in the TVSH. In this poster, we emphasize the importance of the 'outputs' of the two-systems to the specification of their respective operations. We argue that once this point is appreciated, it becomes evident that the TVSH is entirely compatible with a perspectival account of visual experience.

## **7. Adaptation of ultra-rapid visual responses on a human upper limb muscle during visuomotor rotation**

Chao Gu (1)\*, J. Andrew Pruszynski (1), Paul L. Gribble (1), Brian D. Corneil (1)

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We have the ability to rapidly adapt our motor commands in novel environments. For example, during the visuomotor rotation task, the sensory-mapping of the visual representation of the target is altered, so that a new motor command is required to accurately reach the target. Previous work has demonstrated an ultra-rapid (70-110 ms) stimulus-locked response (SLR) on human upper limbs to visual stimulus targets. Here we investigated the change in the tuning of the SLR pre- (no rotation), peri- (60° counter-clockwise [CCW] rotation) and post- (no rotation) visuomotor rotation in 8 subjects while they performed center-out reaches to 8 equidistance targets. While they performed the task we recorded EMG activity from the pectoralis muscle. 7 out of the 8 subjects had a SLR pre-visuomotor rotation, and the preferred direction (PD) of the

SLR was similar to the PD of the movement-related activity in the pre-condition. During the 60° CCW rotation, the movement-related activity rotated on average  $56^\circ \pm 8^\circ$  CW relative to the visual target to counteract the visuomotor rotation, however the SLR response rotated on average  $17^\circ \pm 8^\circ$  CW in the new adapted state. Post-visuomotor rotation, both the movement-related activity and the SLR returned to the pre-visuomotor rotation PD.

## **8. The Somatosensory System Supports Motor Learning by Observing**

Heather R. McGregor (1), Joshua G.A. Cashaback (1), Paul L. Gribble (1)\*

(1) *Western University, London, Ontario, CANADA*

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Motor learning involving physical practice results in sensory-motor cortical plasticity. Here we tested if the somatosensory system is also involved in motor learning by observing. In Experiment 1 we applied nerve stimulation to either arm while subjects observed a tutor performing a force field learning task using the right arm. Stimulation occupied somatosensory cortical processing with irrelevant input during observation. Stimulation delivered to the right arm (same arm used by the tutor) disrupted learning whereas stimulation delivered to the left (opposite) arm did not. This suggests that a somatosensory representation of the observed effector is necessary, and hence must be unoccupied, for motor learning by observing to occur. In Experiment 2 we assessed changes in primary somatosensory (S1) cortical processing following motor learning by observing by measuring somatosensory evoked potentials (SEPs). The N20-P25 component, which is generated by S1, increased in amplitude only in subjects who observed the tutor learning. Moreover, SEP increases were correlated with subjects' subsequent behavioural motor learning scores. These experiments demonstrate that the somatosensory system supports motor learning by observing.

## **9. Visual and presaccadic activity in Area 8A of the dorsolateral prefrontal cortex in macaque monkeys**

Kelly R. Bullock (1)\*, Florian Pieper (2), Adam Sachs (3), Julio C. Martinez-Trujillo (4)

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(2) *University Medical Center Hamburg-Eppendorf (UKE), Hamburg, GERMANY*

(3) *University of Ottawa, Ottawa, Canada, (4) University of Western Ontario, London, CANADA*

The dorsolateral prefrontal area 8A is thought to play a role in transforming visual signals into goal-directed behavior. Neurons within this area exhibit visual, movement, and visuomovement responses during oculomotor tasks. However, the receptive fields and movement-related fields have not been well characterized in this area. Here we recoded the responses of neurons in area 8A of two *Macaca fascicularis* while the animals made visually-guided saccades to a peripheral sine-wave grating stimulus positioned at one of 40 possible locations. To determine the receptive fields and movement-related fields, we integrated average firing rate at each location during stimulus presentation (visual field) and prior to saccade onset (motor field). We observed that saccade endpoints are less accurate at larger eccentricities. Furthermore, we found that the width of the receptive field scales with eccentricity and that the majority of cells preserved the same angle across eccentricity.

## **10. Multiple Object Representation and Attentional Filtering in Primate Prefrontal Cortex**



Lyndon Duong (1)\*, Florian Pieper (2), Julio Martinez-Trujillo (1)

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In general, neuronal firing responses to simultaneously presented stimuli do not match the sum of responses to individually presented stimuli. We implanted multi-electrode arrays in the lateral prefrontal cortex (IPFC) of two non-human primates and recorded spiking activity from neurons during a task that required the animals to covertly attend towards one of four spatial targets on a computer screen. Similar to findings reported in other areas of cortex, we found that when presented with many stimuli, firing rates from neurons in IPFC resemble the average of firing rate responses to individual stimuli. Interestingly however, populations of neurons tuned for the visual hemifield ipsilateral to the implants showed a more suppressed activity when presented with multiple stimuli than contralaterally tuned neurons. Furthermore, attention towards a neuron's preferred location shifted its response towards a winner-take-all computation, whereas attentional responses to non-preferred locations resembled no-attention averaging computations. Our findings reveal that IPFC neurons selective for the ipsilateral or contralateral hemifield may be governed by different underlying connectivity.

## **11. Training history potentially influences behavioural performance and selectivity of dorsolateral prefrontal neurons**

Theda Backen (1)\*, Julio C. Martinez-Trujillo (1)

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Selective visual attention acts as a filtering mechanism to discriminate behaviourally relevant from irrelevant information. The attentional signal is hypothesized to arise in the dorsolateral prefrontal cortex of the primate brain. We studied neural interactions during target-distractor filtering, by recording from 96-channel microelectrode arrays while the monkeys performed a behavioural task in which we manipulated task difficulty. We realized that the training history of the animals had an effect on both behavioural performance and neuronal sensitivities. Monkey R, who had been exclusively trained on this kind of target-distractor filtering task, showed great behavioural performance and strong neural selectivity for the attended location. On the other hand, monkey S has had previous extensive training on a motion discrimination task, which resulted in strong neural selectivity for motion direction along with overall weaker behavioural performance. These results might give valuable insight to the building of expertise in primate dorsolateral prefrontal cortex as well as provide useful suggestions for the reuse of animals in research.

## **12. Eye-movement Behaviour and Kinematics of Non-Human Primates in a Virtual Environment**

Benjamin Corrigan (1,2)\*, Roberto Gulli (1,2), Guillaume Doucet (1,2), Julio Martinez-Trujillo (1)

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Virtual environments (VE) have become a popular way of studying cognition in humans, but they are rarely utilized in primate neurophysiology despite numerous advantages. Two monkeys performed a context-object associative learning task within a VE while we recorded eye positions to investigate the effects of task demands and learning on oculomotor behaviour. We found that both saccade rate and fixation pattern changed as a function of trial epoch, suggesting that the monkeys were changing their behaviour in line with task demands. We also found that navigating did not have an effect on the saccade kinematics of peak velocity compared with static presentations. The research shows that navigating virtual environments does not change kinematics from static images. Saccades can generate noise in Electrophysiological recordings, and validating similarity in kinematics ensures that changes are not due to kinematically different saccades. This is important for future analysis of electrophysiological recordings in the hippocampus and PFC.

### **13. Human perirhinal cortex supports judgements of recent frequency and cumulative long-term exposure to concepts**

Devin Duke (1)\*, Ben Bowles (1,2), Chris B. Martin (4) Ken McRae (1), Stefan Köhler (1,3)

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Recognizing that an environmental stimulus is something you have encountered requires the integrity of perirhinal cortex (PrC). Most research has probed this functional role based on recent laboratory learning. It is currently unclear whether PrC also contributes to recognition when learning takes place cumulatively over extended time periods, and when assessment of the degree of prior exposure is required. Guided by neurophysiological findings that neurons in primate PrC signal not only recent object exposure but also cumulative long-term familiarity, we predicted a critical role for PrC when humans judge their cumulative long-term familiarity with concrete concepts. In three experiments, we found that a patient with a left anterior temporal lobe resection that included PrC, but spared the hippocampus, exhibits abnormalities in making such judgments. An fMRI experiment in healthy individuals identified a left PrC region that tracked both perceived cumulative levels of long-term familiarity and recent experimental exposure to a large set of concepts. These findings extend the functional role of PrC to the assessment of cumulative concept exposure over the long-term. PrC may be a structure that bridges functions related to recognition of prior occurrence with the representation of conceptual knowledge that is distilled from repeated object encounters.

### **14. Autonomic Contributions to Adaptive Memory**

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Studies demonstrating a mnemonic benefit for encoding words in a survival scenario have revived interest in how human memory is shaped by evolutionary pressures. Prior work on the survival-processing advantage has largely examined cognitive factors as potential proximate mechanisms. The current study, by

contrast, focused on autonomic emotional arousal. Guided by the idea that a survival scenario implies threat, we combined measures of heart rate (HR) with affective ratings to probe the potential presence of fear bradycardia - a parasympathetically dominated HR deceleration triggered by threat. We replicated the mnemonic advantage in behaviour, and found that the survival scenario was rated higher in negative arousal than a commonly used control scenario. Critically, words encountered in the survival scenario were associated with more extensive HR deceleration, and this effect was directly related to subsequent recall performance. Our findings identify autonomic emotional arousal as a potent proximate mechanism for the survival processing advantage.

## **15. Enhanced recognition for spectrally degraded sentences**

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Although speech researchers have found that participants have poorer long-term memory when speech is degraded (e.g., Pichora-Fuller, Schneider, & Daneman, 1995; Murphy, Craik, Li, & Schneider, 2000), these findings are at odds with studies that have found enhanced memory for masked text (Nairne, 1988; Hirshman, & Mulligan, 1991). The former speech studies have typically tested memory for lists of unrelated words, and as such they may have underestimated the role of elaborative semantic processes (c.f. Craik & Lockart, 1972; Craik & Tulving, 1975) hypothesized to enhance memory for masked text (Mulligan, 1996). In the current experiment, we found that participants remembered degraded spoken sentences better than clear sentences. In a second experiment, we found that this degradation-enhanced memory persisted even when degraded sentences were matched for intelligibility with clear sentences, with both eliciting nearly perfect word-report scores. We interpret these findings as providing converging evidence for the role of semantic elaboration in accurately perceiving, and remembering, degraded spoken sentences.

## **16. How does size affect small and large number estimation? Evidence from a line mapping task**

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Is a group of 6 watermelons perceived as having a different number of items than a group of 6 apples simply because watermelons are physically larger than apples? The current study asks under which conditions physical size can affect numerosity estimation. We employed a line mapping task that did not require explicit comparison or verbal estimation of numerosities. Adult participants were briefly presented with the digits 2-8 or groups of 2-8 dots in 3 different physical sizes and were asked to estimate the position of a presented numerosity on a vertical line from 0-10. The influence of physical size on number estimation was modulated by notation and numerosity range; physical size affected number estimation only in non-symbolic notations in numerosities above 4 dots, when counting was not possible, and rough estimation was necessary. These results are in line with more recent studies suggesting that the influence of continuous properties (such as physical size) on number estimation and comparison is not constant but highly affected by different task-related factors.

## **17. Common and distinct brain regions support symbolic and nonsymbolic numerical magnitude processing: A functional neuroimaging meta-analysis**

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Researchers have canvassed the brain in search of brain systems that support symbolic and nonsymbolic numerical magnitude processing. There is a lack of convergence among neuroimaging studies examining whether number is represented abstractly or if number representations in the brain are format dependent. The current study used activation likelihood estimation (ALE) to conduct the first quantitative meta-analysis of 59 empirical neuroimaging papers examining neural activation during symbolic and nonsymbolic numerical magnitude processing. Foci were compiled to generate probabilistic maps of activation for symbolic and nonsymbolic numerical magnitudes. Conjunction analyses revealed overlapping activation for symbolic and nonsymbolic numbers in regions in the frontal and parietal lobes. Contrast analyses revealed specific bilateral parietal activation during symbolic numerical magnitude processing. A right lateralized fronto-parietal network was specifically activated during nonsymbolic numerical magnitude processing. Therefore, common and distinct brain regions support symbolic and nonsymbolic number processing. This suggests that the human brain hosts both abstract and format dependent representations of numbers.

## **18. Measuring symbolic numerical processing in adults**

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In the field of numerical cognition, ordinality, the sequence of numerals, has received less attention than cardinality, the number of items in a set. Therefore it is unclear whether numerical effects generated from ordinality and cardinality tasks are associated, and whether they relate to math achievement and more domain-general variables in similar ways. To address these questions, sixty adults completed ordinality, cardinality, visual-spatial working memory, inhibitory control and math achievement tasks. The numerical distance effect from the cardinality task and reverse distance effect from the ordinality task were reliable but not associated with one another. Additionally, both distance effects predicted independent unique variance in math scores, even when visual-spatial working memory and inhibitory control were included in the regression model. These findings provide support for dissociation in the mechanisms underlying cardinal and ordinal processing of number symbols and thereby highlight the critical role played by ordinality in symbolic numerical cognition.

## **19. Enhancing social and emotional functioning in frontotemporal dementia: Effects of oxytocin and emotional mimicry**

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Behavioural variant frontotemporal dementia (bvFTD) is a neurodegenerative disorder characterized by impaired socioemotional behaviour, including emotion recognition and empathy deficits. The neuropeptide oxytocin has recently received attention as a possible treatment option to manage these symptoms. Oxytocin has been associated with enhanced emotion recognition in healthy adults, and improved neuropsychiatric behaviours in patients with bvFTD. Emotional mimicry has also been identified as a potential compensatory tool for emotional deficits. However, the effects of oxytocin and emotional mimicry on emotion recognition performance in patients with bvFTD have yet to be examined. Presently, in a double blind, placebo controlled, randomized cross-over design, patients receive intranasal oxytocin or placebo and complete a behavioural emotion recognition task. Participants are asked to view or imitate videos of emotional expressions, and select an appropriate emotional label for each one. Preliminary analyses suggest that disgust recognition accuracy is greater following expression imitation versus viewing across treatment conditions. This is particularly interesting given the limited information available regarding symptoms related to impaired disgust processing, such as rotten food consumption and unhygienic behaviour, and the early degradation of the insula in bvFTD. These findings could contribute to the development of much needed novel treatments for this debilitating disorder.

## **20. The Effects of Perceptual and Working Memory Load on Emotional Distractor Processing**

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Throughout our day-to-day activities, we are subjected to numerous task-irrelevant stimuli that compete for our attention. Previous research has demonstrated that the extent to which task-irrelevant distractors are processed is mediated by the nature of the cognitive task and the level of processing load. However, this has not been tested for emotional stimuli, which is harder to extinguish, and is assumed to interact with processing load in a uniform manner. Thus, the interaction between cognitive task, load type and emotional distractors remain unclear. In the present study, participants were presented with emotional task-irrelevant distractors during a perceptual and a working memory task, under varying levels of load. In line with predictions, we found that emotional distractors increased behavioural interference during low but not high perceptual load. Conversely, emotional distractors increased behavioural interference during high but not low working memory load. This may suggest that processing emotional distractors relies on both the nature of the cognitive task and the level of load. Additionally, these results raise the important possibility that similar resources are used during working memory load and attentional processes that are important for emotion regulation.

## **21. Enhanced subjective awareness and “blindsight” for fear conditioned stimuli under Continuous Flash Suppression**

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In prior work, we have shown that under conditions of perceptual rivalry, fearful expressions not only have privileged access to awareness relative to neutral or disgusted expressions, but are more frequently detected in the absence of awareness, a phenomenon akin to “affective blindsight.” Recently, it has been



argued that such advantages are strictly due to differences in low-level visual features, rather than to specific emotional qualities of the stimulus. To test this alternate hypothesis, we conducted a Continuous Flash Suppression task involving perceptually matched fear conditioned stimuli. Participants were presented with suppressed neutral faces that were either previously paired with an electric shock (CS+) or not (CS-), and asked to localize the quadrant in which faces were presented. Results showed that, among participants who demonstrated successful fear conditioning, accuracy, subjective awareness and “blindsight” were increased for the CS+ compared to the CS-. These findings provide further evidence of enhanced processing of fear-related stimuli at a pre-conscious and conscious level, and that this effect is driven by the emotional salience of fear.

## **22. Levodopa impairs reward learning in healthy young adults**

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Cognitive impairments are now recognized in Parkinson’s disease. Some of these deficits owe to disease pathology itself whereas others are due to paradoxical effects of dopaminergic medications, such as levodopa. The *dopamine overdose hypothesis* proposes that dissimilar effects of medication on cognition depend on baseline endogenous dopamine levels in underlying brain regions. We sought to directly test this prevalent theory. We tested healthy young adults, who presumably have optimal endogenous dopamine levels, in two sessions. Participants received 100/25 mg of levodopa/carbidopa in one session and an equal volume of placebo in the other. During each session, participants completed a probabilistic reversal learning task. We found that healthy adults learned more poorly on levodopa compared to placebo. Our findings suggest that baseline endogenous dopamine levels determine the effects of dopaminergic medications on cognition, independent of Parkinson’s disease pathology and in spite of normal dopamine buffering capacity. Partitioning which cognitive functions are helped versus hindered by medication and improving our understanding of the underlying psychopharmacology of these effects is important for improving treatment strategies in Parkinson’s disease.

## **23. Does dorsal striatum mediate stimulus-response habit learning or decision-making?**

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We tested the prevalent contention that dorsal striatum (DS) mediates later-stage stimulus-response learning when responses become habitual. We previously demonstrated that DS does not mediate early stimulus-response learning but rather underlies decision-making. Using functional magnetic resonance imaging, we examined striatal brain activity during later-stage stimulus-response learning (performance accuracy >90%). Fourteen participants (7M, 7F) learned to associate abstract images with left or right button-presses during an initial explicit study phase. These pairings were reinforced with (Session 1) and without feedback (Session 2). Session 3 measured whether stimulus-response associations had formed habits. DS activity correlated with stimulus-response events only during Blocks 1-3 of Session 1 when response times and accuracy suggested deliberation in responding. No significant DS activity occurred for

Blocks 4-12 or in Session 2, when responses times and accuracy had plateaued, though stimulus-response associations had not formed habits in Session 3. We conclude that DS underlies decision-making that requires deliberation and not stimulus-response habit learning. In Parkinson's disease (PD), DS is significantly dopamine depleted. Increasingly, DS is shown to mediate cognitive functions. Elucidating DS-mediated cognition improves our understanding of cognitive dysfunction in PD. These results clarify the cognitive profile in PD and guide dopaminergic therapy.

## **24. Dorsal striatum mediates cognitive control, not cognitive effort, in decision-making**

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**Background:** Whether the dorsal striatum (DS) mediates cognitive control or cognitive effort in decision-making is unclear because as cognitive control demands of a task intensify, cognitive effort demands increase proportionately. We implemented a task that disentangled cognitive control and cognitive effort to specify DS' role in decision-making. **Methods:** A Stroop task with simultaneous blood-oxygenation-level-dependent response (BOLD) measurement was used. Participants selected the physically larger number of a pair. Discriminating smaller versus larger physical size differences requires greater cognitive effort, but does not require greater cognitive control. We also investigated interdimensional conflict (*e.g.*, 2 6). Selections in this incongruent case require greater cognitive effort and greater cognitive control to suppress responding to the irrelevant dimension. **Results:** Behavioural interference occurred in both conditions. DS BOLD signal only correlated with interference due to increased cognitive control requirements. **Conclusions:** Our findings support the increasingly accepted notion that DS mediates cognitive control specifically and does not index cognitive effort.

## **25. Complexity and Missing Information Measures in Tinnitus**

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**Background:** Common cause for tinnitus is auditory deafferentation with or without hearing loss. Little is known on how this auditory deprivation influences global information processing in the brain. Here we address this study of understanding dynamic complexity present in multiple brain regions, and its relation to identify "missing" information for characterizing the disease state of tinnitus. **Methods:** Two types of information entropy measures on resting-state EEG data of 264 healthy controls and 129 tinnitus patients are used: (1) spectral entropy (SE) and (2) permutation entropy (PE), for accounting higher richness of complexity patterns in frequency and time domains. **Results:** Increased spectral power and SE scores in

theta band indicate the recruitment of large scale spatial cortical networks present in controls, compared to tinnitus. Beta and gamma band activities in tinnitus demonstrate the increasing degree of complexity in temporal, frontal and occipital lobes. Our PE calculations with small time delays imply less information entropy in temporal and occipital areas of controls, compared to tinnitus patients and vice-versa for higher delays. **Implications:** Tinnitus patients extract more information via carrier waves (theta) from central brain areas than controls, whereas controls can extract more information from sensory areas, presumably picking up changing information (gamma).

## **26. Modeling the relationship between the anatomical structure and the functional connectivity of the brain**

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Neuroimaging allow to study the structural and functional connectivity of the brain which led to identify the existence of a relationship between the structure and function. Our goal is to develop a model which could be beneficial in finding the exact relationship between the structure and function of the brain. We propose the generalized Ising model, an advancement of the classical Ising model to accomplish this goal. According to recent suggestions, the global dynamics of the resting brain can be explained at the critical temperature of the classical Ising model by a collection of spins. In this model there is no relationship between spins and brain regions, but in the generalized Ising model each spin describes the behavior of a particular patch of cortex. This was accomplished by introducing couplings which are proportional to the number of fibers connecting the regions. Simulation of the Ising models has been implemented for different temperatures (only variable in the model). We compared the changes in the system with temperature. Calculated global properties such as degree and efficiency was maximized at a particular temperature providing insight about a state of the generalized Ising model that could be compared with functional connectivity of the brain.

## **27. Science as a Problem Solving Activity: A Framework for Teaching Philosophy to Science Students**

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An increasingly pressing challenge for philosophers of science interested in direct collaborative work with scientists is that of bridging the disciplinary gap. Philosophers teaching university-level courses directed at science students have struggled with the widespread assumption that doing philosophical work requires an extensive background in the discipline. This is a problem because the methods that philosophers develop may prove useful to scientific work. Our aim is to show that treating scientific inquiry as a problem solving enterprise provides a useful scaffold for introducing scientists to philosophy of science. Adapting a framework developed by Banville (in prep.), we show that using the familiar notions of problem solving and heuristics enables students to analyze real cases taken from their field. The idea is to develop the practical skills associated with philosophical discourse. The poster outlines each step of this teaching strategy. The goal to provide students with insights that will make them better problem solvers and thus, more successful scientists. This is a key aspect in developing productive collaborations between scientists and philosophers.

## **28. Competent to continue treatment? The case of impulse control disorders in deep brain**



## **stimulation for Parkinson's disease.**

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This article examines the fictional but realistic case of Mr. Smith, a Parkinson's disease patient who is treated through deep brain stimulation and who develops compulsive gambling, an impulse control disorder. Mr. Smith refuses to be undergo treatment for his compulsive gambling. Should physicians respect Mr. Smith decision? Deep brain stimulation for Parkinson's is carried out by surgically implanting electrodes into the subthalamic nucleus. Stimulation has been shown to be more effective in Parkinson's than the standard medical treatment with levodopa. However, stimulation can sometimes cause side-effects, among which impulse control disorders. In this article I make two arguments. First, the deep brain stimulation device is a threat to Mr. Smith's autonomy, because it imposes on him a behavior, namely compulsive gambling, which is unrelated to his personality and his pre-surgery preferences. Secondly, I examine Mr. Smith's decision making capacity while under stimulation. In this case, stimulation creates Mr. Smith's passion for gambling, a value that is both unstable and unlikely to be plausibly considered his own. Therefore, Mr. Smith falls short of the reasoning requirement for decision-making capacity. I conclude by putting forth that pre-surgery advance directives are the most effective way to deal with patients like Mr. Smith.

## **29. Classifying perception and imagination of rhythms and speech from EEG**

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The neural processes involved in the perception of music are also involved in imagination. This overlap can be exploited by techniques that attempt to classify the contents of imagination from neural signals, such as signals recorded by EEG. Successful EEG-based classification of *what* an individual is imagining could pave the way for novel communication technologies, such as brain-computer interfaces. Our study explores whether we can accurately classify perceived and imagined rhythms and short repetitive phrases from EEG data. Participants heard and then imagined four short, repeated speech phrases and four rhythms that matched the speech phrase rhythms while undergoing EEG recordings (64-channel BioSemi system). Our primary goal is to reliably distinguish each stimulus based on its rhythmic pattern, using EEG signals. We hypothesize that we will be able to classify which phrase or rhythmic pattern was being heard, or being imagined, from the EEG data. Using ERP analyses and machine learning techniques, the preliminary analyses on pilot tests show promising results. Further results will be presented at IBMIS 2015.

## **30. Audiovisual integration of musical information modulates the P300**

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Integration of auditory and visual information is important to both language and music. In the linguistic domain, audiovisual integration alters event-related potentials (ERPs) at early stages of processing (the mismatch negativity (MMN)) as well as later stages (P300 (Andres et al., 2011)). We investigated whether musicians show audiovisual integration of music similar to readers, and at what points in the processing stream integration occurs. Musicians and non-musicians simultaneously saw and heard musical intervals

that varied in whether visual and auditory information was congruent or not. Both the MMN and P300 were larger for auditory deviants than standards. However, only the P300 was larger when the deviants were congruent. Both groups showed a congruency effect, but their respective scalp distributions differed. We propose that early in the processing stream, visual information may guide interpretation of auditory musical information, leading to a larger MMN when auditory and visual information mismatch. At later attentional stages, integration of the auditory and visual stimuli leads to a larger P300 amplitude. Thus, audiovisual musical information is integrated similarly to linguistic information at later stages of processing, but not as early or automatically as language.

### **31. Timing and changes of motor area excitability in beat perception**

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Humans can synchronize their movements to the 'beat' of musical rhythms, and the brain's motor system is recruited when humans hear rhythms with a beat. Past research suggests that motor excitability increases during beat perception, however, the timing of excitability modulation in relation to the beat has not been characterized. Here, we use transcranial magnetic stimulation (TMS) over primary motor cortex to elicit motor-evoked potentials (MEPs, which index motor system excitability) in the first dorsal interosseous muscle (FDI) of the dominant hand, while participants (n=6) passively listened to rhythms with or without a beat. Single pulse TMS (110% of motor threshold) was delivered at one of five temporal positions before beat positions. The results showed that MEPs were indeed greater for beat than nonbeat rhythms, especially at 10% and 5% of the beat interval before the beat onset ( $p = 0.02$  &  $0.05$ , respectively;  $p < 0.05$  for the interaction between beat presence in rhythms and asynchrony of TMS delivery). These results indicate that motor system excitability is dynamically modulated during beat perception, such that motor excitability peaks around 5-10% before auditory beat onsets.

### **32. Investigating music-based rhythmic auditory stimulation for gait rehabilitation: Weak beat perceivers perform better without instructions to synchronize**

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Music-based rhythmic auditory stimulation (RAS) is a cueing technique used to rehabilitate abnormal gait, typically involving synchronizing footsteps with the beat. However, instructions to synchronize may be detrimental to individuals who have difficulty perceiving the beat in music, such as people with Parkinson's disease, because of increased cognitive load. The present study evaluates how beat perception skills influence gait responses to RAS when instructed to synchronize steps with the beat versus when permitted to walk freely. Healthy participants walked on a pressure-sensor walkway to music that they rated to be high in groove (a quantification of 'desire to move to the music'). Beat perception was evaluated using the Beat Alignment Test from the Goldsmiths Music Sophistication Index v1.0. As predicted, instructions to synchronize facilitated gait in strong beat perceivers, whereas walking freely facilitated gait in weak beat perceivers. This instruction x beat perception interaction occurred significantly for stride width, an indicator

of balance, and marginally for stride length. Results support the premise that RAS should be tailored to beat perception skill: weak beat perceivers exhibit greater improvements if there is no pressure to synchronize steps to the music.

### **33. Attention and presence of a beat modulate neural entrainment to non-repeating rhythms**

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During rhythm perception, steady-state evoked potentials (SS-EPs) at the frequency of the beat have been observed in electroencephalograms (EEG; Nozaradan et al., 2011, 2012). In previous studies, participants actively attended to the stimuli, which were isochronous sequences or repeating rhythms. Here we assessed whether neural enhancement of SS-EPs at beat-related frequencies occurred when (1) participants did not attend to the rhythms, and (2) the rhythm was novel and did not repeat. Participants listened to non-repeating beat (regular) and nonbeat (irregular) rhythms. In half of the trials, they attended to the rhythms, and in the other half, they performed a concurrent distractor task. Beat-related SS-EPs were observed in the beat rhythms, indicating that SS-EP enhancement occurs even in non-repeating rhythms. These SS-EPs were larger for attended than unattended beat rhythms. For nonbeat rhythms, attention did not enhance the SS-EPs at beat-related frequencies. Therefore attention did not simply enhance all SS-EP responses, regardless of their relation to the beat, but only enhanced the response at beat-related frequencies, and only when a beat was present in the rhythm. SS-EPs therefore appear to be a marker of beat perception even in non-repeating rhythms, and are enhanced by attention.

### **34. Comparing Human and Nonhuman Primate Brain Responses to Auditory Sequences**

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Humans have the ability to perceive and move to the 'beat' in rhythm. This complex behaviour may be unique among primates, and involves extracting regularities from complex, non-isochronous auditory sequences and synchronizing movements to those regularities. To characterize cross-species differences in neural processing of rhythm and beat perception, we compared brain responses in humans and a macaque monkey using electroencephalography (EEG). EEG was recorded while participants listened passively to auditory sequences which consisted of white noise bursts (65ms) separated by time intervals. Intervals were structured to create 5 types of sequences: i) isochronous (at three rates), ii) random, iii) strongly beat-based, iv) weakly beat-based, or v) non-beat-based. We compared the two species' evoked and induced responses in EEG, at various frequency bands (e.g., beta and gamma) to isochronous and random sequences. We also compared steady state evoked potentials (SSEPs) to the low-frequency (1-5 Hz) regularities in the structures of non-isochronous sequences (iii-v). Similarities and differences between species' brain responses reveal common and distinct aspects of neural processing of auditory sequences.

### **35. Familiarity with music increases stride length in rhythmic auditory cueing**

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Rhythmic Auditory Stimulation (RAS) is a method of gait rehabilitation that involves synchronizing footsteps to a metronome or musical beats. Although RAS with music can ameliorate gait abnormalities, outcomes vary, possibly because music properties differ across interventions. To optimize future interventions, we assessed how the familiarity of music may influence gait. **Method:** Familiarity was manipulated using two methods: (1) inherent familiarity with songs and (2) increased familiarity through repeated exposure. Healthy adults walked to 2 songs they rated most familiar and 2 songs rated to be the least familiar from a pre-existing catalogue of songs. Stride length, stride time, and stride velocity were measured using a 16' pressure-sensory walkway with a sampling rate of 160 Hz. Subsequently, participants passively listened to their playlist repeatedly. Then, their gait while walking to their playlist was re-examined. **Results:** High-familiarity music elicited significantly longer strides than low-familiarity music, but no effect of repeated exposure was observed. **Implications:** As Parkinsonian gait is characterized by small shuffling steps, RAS with music that is inherently familiar may be able to increase stride length to help ameliorate this irregularity. Future studies should investigate whether this effect persists in a population with Parkinson's disease.

### 36. Children's Numerical Magnitude Processing Predicts Subsequent Early Reading Skill

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Children's reading and mathematical abilities develop in parallel. We examined how numerical magnitude processing contributes to this association. Kindergarteners performed digit- and dot-comparison tasks to assess processing of symbolic and non-symbolic quantity, along with a test of phonological awareness (PA), a well-studied predictor of reading success. We then followed up a year later in the first grade by testing children's word and nonword reading. As expected, PA correlated strongly with both reading tests. However, magnitude comparison – and in particular digit magnitude comparison – also accounted for unique variance in reading scores. We next examined how children's rapidly naming (RAN) of digits might also predict reading scores, focusing in particular on differences in naming of high- versus low-magnitude digits. Low digits were easier to name than high digits, reflecting the well-established numerical magnitude effect. But importantly, the increased effort in naming high-magnitude digits explained a significant amount of variance in reading familiar words, but not nonwords. Overall, our findings support the theory that reading and math build on common neurocognitive substrates supporting learning of symbol-semantics mappings. This expresses itself in how children encode whole-word forms for reading and how they learn numerical representations of digits.

### 37. Eyetracking of Coarticulatory Cue Responses in Children and Adults

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Studies examining sensitivity to coarticulatory cues during spoken word recognition have typically examined children and adults separately. The present study compared sensitivity to coarticulatory cues in school-aged children and adults using eyetracking. Children and adults listened to words containing congruent and incongruent coarticulatory cues while looking at a two-picture display. Contrary to theories positing weakened attention to phonetic detail in children, we observed greater sensitivity to coarticulatory cues in children compared to adults. This effect was related to predictors of reading and language proficiency, and was also modulated by phoneme contrasts such that children were overly sensitive to more salient coarticulatory cues. These findings suggest that children are more sensitive to phonetic detail in speech than adults, and the phonological skills underlying this sensitivity are related to individual differences in reading and language ability.

### **38. “She will drive the \_\_\_\_”: Verb-based prediction in individuals with Parkinson disease.**

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Cognitive changes in Parkinson disease (PD) affect language processing, including sentence comprehension impairments, difficulties with processing verbs, and discourse impairments. In many theories of language comprehension, efficient language processing depends on successful implicit prediction of upcoming concepts and grammatical structures. Such prediction processes, in part, may be regulated by the neural dopaminergic system, which is markedly impaired in PD. In non-language tasks, persons with PD (PwPD) are impaired in prediction, sequencing, and probabilistic learning. However, the contributions of these dopaminergic-mediated prediction and probabilistic learning processes to language processing impairments in PD remain unexplored. We tested whether PwPD are impaired in implicit prediction during auditory language processing. The visual-world paradigm was used to investigate implicit predictive eye movements based on verb meaning. Participants listened to semantically predictive and non-predictive sentences while viewing picture stimuli. Both PwPD and controls showed prediction of upcoming nouns from verbs when hearing sentences like “She will drive the car.” (Intercept to Quadratic time terms: all  $p$ 's < .02). Furthermore, PwPD performed equivalently to controls (all  $p$ 's > .3). These results are surprising given the literature, suggesting either that PwPD have normal linguistic prediction, or that more challenging conditions for prediction are required to reveal PD impairments.

### **39. Can transcranial direct current stimulation facilitate motor performance in a random sequence reaction time task? Implications for vegetative state patients.**

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There is evidence that some vegetative state (VS) patients are covertly aware but unable to demonstrate their awareness with motor behaviour, perhaps due to a structural disruption in their motor system. Transcranial direct current (tDCS) improves motor learning in healthy controls on tasks that involve training. Consequently their results cannot be extrapolated to vegetative state patients, as motor training with these patients is particularly challenging. In this study, we investigate whether one session of tDCS can facilitate motor performance in the absence of training on a random sequence motor reaction time task. Specifically, 40 healthy participants were randomly assigned to receive either sham or anodal tDCS, and to



perform the task with or without training. All participants completed a 5-minute baseline task, 20 minutes of tDCS over the primary motor cortex, and a 5-minute post-tDCS task. In the training condition, participants practiced this task during stimulation. In the non-training condition, participants watched a 20-minute video. A mixed design ANOVA was conducted separately for each task with time point as the within subject factor, and tDCS type as the between subject factor. We find no significant differences in the performance for either group. Implications for VS patients will be discussed.

#### **40. Detecting Preserved Emotional Processing in Disorders of Consciousness (DOC)**

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Recent advances in our understanding of the residual cognitive abilities of patients with DOC suggest that, despite the absence of overt responses, such patients can exhibit a considerable degree of cognitive functioning. Here, we asked whether such patients also exhibit some preservation of emotional functioning when probed with tasks that do not require such overt responses. To examine this possibility, we tested a DOC patient and a group of healthy control participants using facial electromyography (EMG) to measure activity in the *zygomaticus major* and *corrugator supercilii* muscles in response to auditorily presented jokes and non-jokes. We found a remarkable parallel between the pattern of muscle activity elicited by jokes and non-jokes in the DOC patient and healthy control participants. Jokes elicited greater activity in the *zygomaticus major* muscle for both healthy control participants and the DOC patient. Moreover, both the DOC patient and healthy controls demonstrated less activity in the *corrugator supercilii* muscle for jokes relative to non-jokes. These findings suggest that some patients with DOC can derive and express humor in a manner similar to healthy control participants.

#### **41. Assessing the feasibility of time-resolved fNIRS to detect brain activity during motor imagery**

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Functional near-infrared spectroscopy (fNIRS) is a non-invasive bedside optical technique for detecting cortical brain activity. There is an increasing interest in using fNIRS as a brain computer interface (BCI) for patients who lack the physical (but not the mental) ability to respond to commands. Time-resolved is an fNIRS technique that has been previously shown to improve depth sensitivity in comparison to commercially available fNIRS techniques. The goal of this study was to assess the feasibility of time-resolved fNIRS to detect brain activity during a motor imagery task (i.e. imagining playing tennis). fNIRS probes were placed on the scalp over the premotor cortex and supplementary motor area. The experimental paradigm consisted of five cycles of 30 s rest, followed by 30 s motor imagery. Activation in the supplementary motor area and the premotor cortex was confirmed by having subjects perform the same task in an fMRI session, prior to fNIRS. The preliminary results obtained highlight the potential of time-resolved fNIRS as a BCI, which could be adapted for bedside studies of patients with disorders of consciousness.

#### **42. "Can you hear me?" Assessing Auditory Processing in Comatose Patients using fMRI**

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fMRI studies have shown that vegetative state patients retain aspects of language comprehension. Our objective was to extend these fMRI paradigms for the first time to patients in the acute phase of coma. Comatose patients were recruited from the Intensive Care Unit at London Health Sciences Centre and underwent fMRI imaging. A passive auditory language task was used to independently assess sound perception, speech perception and language comprehension on an individual basis. A range of activation patterns were observed in patients. While some patients did not show any neural response to auditory stimuli others had significant auditory, speech perception, and language processing responses similar to healthy control participants. Further studies should continue to elucidate the relationship between the level of auditory processing and the patient's subsequent functional recovery.

### **43. Detection of attentional and perceptual abilities in patients with Disorders of Consciousness using vibrotactile stimulation**

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Disorders of consciousness (DOC), such as the Vegetative State (VS) and Minimally Conscious State (MCS), are diagnosed on the basis of behavioural responses to external stimulation. Patients in the VS do not engage in any purposeful outward responses to commands. In contrast, patients diagnosed as in a MCS show some reproducible markers of awareness and responsiveness. We present a deviant detection paradigm that allows for a more detailed characterization of residual cognition in these patients using vibrotactile stimulation and electroencephalography. In a sample of sixteen patients, the presence or absence of the bottom-up attentional marker reliably distinguished between diagnostic groups. However, the marker of somatosensory perception was not related to any other available clinical measure. This paradigm is a valuable addition for a battery of neuroimaging-based assessments of residual cognition for patients with DOC. Such a battery will more thoroughly characterise the abilities of these patients and may even allow for two-way communication in some cases.

### **44. Decoding conscious experiences in nonresponsive populations**

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Although in our daily lives we engage in many of the same activities as others, we are not privy to their conscious experiences, and can only understand them through their self-reports. Patients who are conscious, but are unable to speak or exhibit willful behavior, are, therefore, unable to report their conscious

experiences to others. Indeed, in most cases, it is impossible to know whether they are conscious or not. We introduce a neural index based on executive function that, in a group of healthy participants, predicted each individual's conscious experience. An anaesthesia study showed that executive function was abolished in deeply sedated unconscious individuals, suggesting that it provides a sufficient condition for consciousness. Finally, this approach provided strong evidence for intact conscious experiences in two severely brain-injured patients with unknown levels of consciousness. These findings have implications for understanding human consciousness, and for the standard of care and quality of life of patients misdiagnosed to be in a vegetative state.

#### **45. Individual differences in intelligence and performance under sedation**

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The relationship between individual cognitive abilities and sedation is poorly understood. In a recent sedation study, in which subjects were presented with an auditory story, we found a graded loss of fronto-parietal network activity across subjects during mild sedation, suggesting an impairment of executive function. Further, the grading suggests that brain connectivity of some subjects is more robust under sedation than others. Response times for a target detection task were also recorded at awake and mild-sedation conditions. A further study was conducted in an attempt to understand why some individuals are more resilient against sedation than others. Participants completed a battery of cognitive tests which could provide a proxy measure of their intelligence, scored according to three factors; short term memory, reasoning and verbal ability. Preliminary results suggest that performance on the reasoning measure predicts both response times in mild sedation and fronto-parietal activity. Stronger reasoning ability may therefore provide a measure of protection against the effects of sedation.

#### **46. Naturalistic paradigms for neuroimaging and bedside measures of conscious awareness**

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Complex, naturalistic stimuli can test for covert awareness in behaviourally non-responsive patients. For patients with poor visual function, we aimed to identify an auditory-only stimulus that could evaluate executive function, a component of conscious experience. Also, we assessed if Galvanic Skin Response could be a suitable method for testing awareness at the bedside. Healthy individuals listened to 4 auditory stimuli in the fMRI scanner. During Galvanic Skin Response recording, an independent group of controls listened to an audio narrative and watched a movie. Behaviourally non-responsive patients were also tested during movie viewing. Using fMRI, an audio narrative was identified that produced widespread brain synchronization between healthy participants, critically in the frontoparietal network. Healthy controls showed highly similar GSR to a suspenseful movie. A locked-in syndrome patient had a similar GSR to controls during movie viewing. The audio narrative can be used for future patient testing, and GSR can be used to test for consciousness at the bedside.

#### **47. Residual sensorimotor function in Disorders of Consciousness**



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In patients with disorders of consciousness (DOC), functional magnetic resonance imaging (fMRI) paradigms that measure brain responses to passive presentations of stimuli (e.g. visual, auditory, emotional) can provide important information on residual functioning in the associated neural systems. To date, motor function in DOC patients has not been explored with passive paradigms, despite the prevalence of motor system impairments and the importance of volitional movement for behavioural assessments of awareness in these patients. We used fMRI to assess the neural response to passive movements of the arm in DOC patients, as compared to 13 healthy controls. Electromyography was also collected to compare muscle activity during passive compared to active movement. Healthy controls showed robust activation in sensorimotor-related regions including M1, S1, and SMA, while a DOC patient showed significant activation restricted to S1. Activation in these regions, induced by somatosensory signals associated with passive movement, could indicate functional preservation of a patient's sensorimotor pathway. Further testing will determine if neural responses to passive movements are associated with diagnosis or prognosis, as well as the potential use of this task for assessing neurological benefits associated with physical rehabilitation.

#### **48. White Matter Tract and Resting State Connectivity Changes in Un-Concussed Rugby Players**

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**Introduction:** Sports-related concussion is considered a rare injury amidst the number of average impacts a player may experience throughout the season. Changes due to these repetitive subconcussive events has not been evaluated. **Purpose:** To use diffusion tensor imaging (DTI) and resting state fMRI to explore changes in major white matter tracts and regional changes in connectivity as a result of repetitive subconcussive impacts. **Methods:** A university level girls rugby team (age 18-22) has been recruited for this study. The girls (n = 53) were assessed at the beginning and end of season using the 3T MRI at Robarts. Diffusion data was extracted for 9 major white matter tracts and connectivity data was analyzed using pairwise t-tests. **Results:** Many tracts had significantly increased FA values, decreased MD values and decreased RD ( $p < 0.05$ , corrected for multiple comparisons). There were multiple regions that showed decreased connectivity at the end of season. **Conclusion:** Though it is difficult to determine the underlying physiology, these DTI changes are consistent with remyelination, possibly as a recovery mechanism, resulting in disrupted communication between brain regions.

#### **49. How to become an expert: The role of sleep in the mastery of procedural skills**

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With enough practice and sleep we adopt strategies that become automatic and subsequently refine to become an “Expert”. It is not known whether sleep is involved in the mastery of new skills or whether this is dependent on rapid eye movement (REM) or non-REM (NREM) sleep. Here we sought to identify the post-learning changes in sleep as individuals progress from Novice to Experts on the Tower of Hanoi task (ToH). Fifteen young adults underwent several nights of post-training polysomnographic recordings where subjects performed the ToH task to arrive at an optimal solution. When the task was novel, post-training fast spindle density increased significantly. On the night where subjects become Experts and had a significant increase in accuracy on the task, they show increased REM sleep vs. Control, where spindles in NREM2 also increased in amplitude and duration which was significantly correlated with overnight improvement in accuracy. Re-exposure to the task one-week after the subjects became Experts, resulted in increased NREM sleep vs. Control. This study identifies, for the first time, that increased REM sleep and spindles are involved in the acquisition of expertise of a new skill, but NREM sleep is involved in the refinement of an already mastered skill.

## **50. Expert and crowd-sourced validation of an individualized sleep spindle detection method employing complex demodulation and individualized normalization**

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**Background:** A spindle detection method was developed that: 1) extracts the signal of interest relative to ongoing “background” sigma activity using complex demodulation, 2) accounts for variations of spindle characteristics across the night, scalp derivations and between individuals, and 3) employs a minimum number of user-defined parameters. **Methods:** Spindles were automatically detected in 15 young healthy subjects. Two experts and a group of non-experts, manually identified spindles from C3 during stage 2 sleep. These spindles were compared between raters and to the automated detection to identify the presence of true positives, true negatives, false positives and false negatives. **Results:** The automated detection method had a high level of agreement and identified spindles with similar characteristics as compared to Expert 1 and the consensus of non-experts, but not Expert 2, who used a different method to visually identify spindles compared to Expert 1 and the non-experts. **Implications:** This method resolves or avoids many of the limitations that complicate automated spindle detection, and performs well compared to a group of non-experts, and importantly, has good external validity with respect to the extant literature in terms of the characteristics of automatically detected spindles.

## **51. Rhythm, reason, and routine: Circadian markers relate to intellectual ability**

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**Background:** Electrophysiological markers of sleep are associated with cognitive abilities measured by intelligence quotient (IQ) tests. However, circadian rhythms also influence sleep. It remains to be investigated whether sleep per-se or circadian factors may account for inter-individual IQ differences. Here, we investigated whether IQ scores were associated with circadian markers. **Methods:** Seventeen subjects completed the Cambridge Brain Sciences (CBS) tests, the Morningness-Eveningness questionnaire and underwent six days of actigraphy. Actigraphic data quantified circadian rhythmicity (acrophase; amplitude; mesor), bed/wake time and sleep duration. Measures were grouped into: IQ scores (Short-term memory; Reasoning-IQ; Verbal-IQ; Total-IQ), circadian typology (morningness-eveningness), circadian rhythmicity, sleep routine, and routine consistency (circadian and sleep routine variability). Multiple regressions were performed on each IQ score, for each data type (typology; rhythmicity; routine; consistency). **Results:** Consistency accounted for a significant proportion of inter-individual variability in Total-IQ, with mesor and amplitude variabilities being the strongest predictors. Rhythmicity accounted for significant variability in Reasoning-IQ and Total-IQ. **Implications:** Deviation from a normal circadian rhythm appears to be negatively associated with cognitive ability, particularly reasoning. This preliminary study indicates circadian factors may play a shared role (with sleep) pertaining to cognitive ability.

## **52. Altered salience network connectivity predicts macronutrient intake after sleep deprivation**

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Although insufficient sleep is a well-recognized risk factor for overeating and weight gain, the neural mechanisms underlying increased caloric (particularly fat) intake after sleep deprivation remain unclear. Here we used resting-state functional magnetic resonance imaging and examined brain connectivity changes associated with macronutrient intake after one night of total sleep deprivation (TSD). Compared to the day following baseline sleep, healthy adults consumed a greater percentage of calories from fat and a lower percentage of calories from carbohydrates during the day following TSD. Subjects also exhibited increased brain connectivity in the salience network from the dorsal anterior cingulate cortex (dACC) to bilateral putamen and bilateral anterior insula (aINS) after TSD. Moreover, dACC-putamen and dACC-aINS connectivity correlated with increased fat and decreased carbohydrate intake during the day following TSD, but not during the day following baseline sleep. These findings provide a potential neural mechanism by which sleep loss leads to increased fat intake.

## **53. Sleep spindles in SWS in relation to IQ**

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Spindles serve as one of the few electrophysiological markers of cognitive abilities, as well as aiding in protecting sleep from external stimuli. Considering this, it still remains to be investigated whether spindles

per se, relate to a person's intelligence quotient (IQ) or good quality sleep, in general. We hypothesized that there will be a positive correlation between spindle density and Reasoning IQ (RIQ), independent of sleep quality. A single night of polysomnography (N=10) was sleep stage scored and spindles were automatically detected. As well, subjects completed the Cambridge Brain Sciences cognitive test battery to measure Verbal IQ (VIQ), RIQ and short-term memory. Surprisingly, spindles in stage 2 sleep did not significantly correlate with IQ. However, spindle amplitude at Cz, Pz and density at Pz during slow wave sleep (SWS) were positively correlated with VIQ. Follow-up analyses revealed that the VIQ subtests together accounted for a significant proportion of variability in VIQ and Digit Span was uniquely related to fast spindle amplitude in SWS over-and-above the other VIQ subtests. Here we demonstrate that fast spindles during SWS correlate with VIQ, suggesting that SWS spindles may have a unique function for verbal cognitive abilities, particularly those that rely on verbal working memory.

#### **54. It's not what you recruit, it's what you do with it: How semantic information improves visual short-term memory**

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Many everyday tasks rely upon visual short-term memory (VSTM). Memory is better for recognizable objects than unrecognizable ones. This might be because recognizable objects are coded more efficiently within visual regions. Or, it might be because additional anterior ventral regions that represent object category are recruited during encoding and/or maintenance. We used functional Magnetic Resonance Imaging (fMRI) to examine the neural representations of semantic content in VSTM. To isolate low-level features from semantics, we generated diffeomorphically warped versions of each image that were matched in visual features but differed in recognizability. We found that recognizable images were remembered more precisely. Overall brain activity was unaffected by recognizability in encoding or maintenance, showing semantics did not recruit additional brain regions. However, multivariate pattern analysis showed that the neural representation within visual regions differed, with stronger coding of semantic details. Our results demonstrate that representations of complex objects in VSTM involves successfully extracting semantic information during encoding in visual areas which are then maintained in parietal regions.

#### **55. The Emergence of the Motor Network in the First Year**

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Motor functions develop rapidly in the first year of life, and brain injury during this critical time can have lifelong effects on quality of life; however, current assessment methods are only weakly predictive of disruption to brain function. The purpose of the current project is to observe the organization of the brain in infants without brain injury using neuroimaging in order to better understand the developing motor network. Functional MRI (fMRI) was collected in adults and infants at 3 and 9 months. Regions of the adult motor network were identified using neurosynth.org, a database for meta-analysis of fMRI studies. An algorithm was used to separate peaks of activation into identifiable nodes, including the supplementary motor area and the left and right cerebella, thalami, pallida, precentral gyri, and rolandic opercula. The

functional connectivity of each region with the others was analyzed using correlation matrices. Functional connectivity between nine brain regions was found to be significantly correlated between infants and adults, suggesting early maturation of the network, and networks could be reliably identified in individuals. The results of this project will be used to identify neurological phenotypes commonly associated with poor motor performance, potentially leading to earlier detection of motor disorders.

## **56. Brain Structure and the Emergence of Neurocognitive Networks**

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The neurocognitive networks that underpin adult brain functions emerge surprisingly during development, by the age of term birth. At present, the effect of atypical development of brain structures on the emergence of functional networks is poorly understood. To address this, we investigated the relationship between structural volumes, resting state networks, and stimulus-evoked activity in the infant brain. We hypothesized that volumetric differences would be seen between healthy neonates and those with brain injury, and that these differences would be reflected in brain function. Seventy babies were scanned in the first postnatal week. All babies were NICU inpatients, and ranged from neurologically healthy to severely brain injured. Anatomical (T1 and T2) and fMRI data were acquired. The lateral ventricles, cerebellum, brainstem, and total brain volume were obtained using semi-automatic segmentation. We also derived five resting state networks and the brain activity evoked by auditory stimulation. The resulting relationship between brain structure and function will be presented. Quantifying the relationship between disruption to brain structure and emerging function has important implications for our understanding of brain development, and a number of clinical applications.

## **57. Dora the Neurocognitive Explorer: Identifying engaging movies for infant fMRI**

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Functional magnetic resonance imaging (fMRI) is a powerful tool to probe the emergence of cognition. Almost no studies have imaged infants awake, as they move more. This limits the range of neurocognitive questions that can be addressed. We aimed to identify engaging stimuli that could capture an infant's attention, make them less likely to move, and improve data quality. We evaluated a range of infant movies which could be used to probe many aspects of emerging cognition. Using an online platform, Amazon's Mechanical Turk, we recruited 100 infants between the ages of 5 and 8 months. Infants were recorded using their webcam while watching movie stimuli. Looking time was used to quantify attentiveness. We found some movies were significantly more engaging than others, and that in these, almost all infants remained engaged for more than 70% of a 10-minute block, giving sufficient power for neuroimaging. Additionally, we demonstrated that infants could be efficiently recruited and tested using an online platform, saving researchers' time.

## **58. Rapid and Coarse Face Detection in the Cortex**

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Subcortical pathways are often assumed to contribute to 'quick and dirty' face detection. To evaluate this assumption, we tested whether faces were more accurately detected in the nasal hemiretina (which preferentially targets the subcortical pathway) than the temporal hemiretina. We found that at the fastest reaction times, faces were more accurately distinguished from visually matched, unrecognizable foils. This rapid detection was category selective, and not found for houses. In a second experiment, we found the rapid detection advantage for faces remained if the spatial frequency of faces and houses was matched. In a third experiment, we investigated the limits of the rapid detection mechanism, by requiring fine visual discriminations. This abolished the rapid route, and faces were not detected more accurately than houses. Critically, in all experiments, performance did not differ between the nasal and temporal hemiretina, implying that cortical rather than subcortical mechanisms are responsible for rapid face-specific detection.

## NOTES









## THANK-YOU

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