ABSTRACT BOOK

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Session: Symposium - A multi-modal approach to understanding the development and dynamics of beat perception

Human and non-human primate comparisons of auditory sequence timing: Can monkeys feel the beat?

Presenting Author: **Grahn, Jessica** (jgrahn@uwo.ca)
University of Western Ontario

Despite the amazing level of shared neural machinery between humans and nonhuman primates, only humans appear to sense and react to musical rhythm. This ability spontaneously occurs early in development, and has played a role in human culture for millennia. Of key interest is our perception of an underlying 'beat' in rhythm, as beat perception is what allows humans to synchronize their movement to rhythm. EEG studies show changes in beta and gamma power when a regular beat is present, in addition to power increases at frequencies related to the beat. fMRI studies have shown that beat perception not only increases activity in motor brain areas (principally the basal ganglia), but it also increases functional neural connectivity (communication) between auditory and motor areas (Grahn and Brett 2007; Grahn and Rowe 2009). This leads to the question: does beat perception induce our desire to move by activating motor areas, or is motor area activity also observed in species that do not appear to move to rhythm? If the latter is true, we must look for other explanations of spontaneous human movement to rhythm. In addition, to date, nonhuman primates have not been shown to be able to synchronize to the beat the way that humans do. Instead of moving 'on' the beat, as humans do, they move after the beat. However, a lack of behavioural evidence is not conclusive. Neural correlates of beat perception (e.g., differential brain responses to rhythmic sequences that do and do not induce a beat) may reveal whether nonhuman primates are sensitive to the beat. Here, we compare the neural responses to rhythm in nonhuman primates (macaques) and in humans for regular temporal sequences in which the beat is clear and irregular temporal sequences in which no beat exists, using both fMRI and EEG. In both humans and macaques, motor areas respond to temporal sequences (both regular and irregular).

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Neural dynamics of beat perception

Presenting Author: **Henry, Molly** (mhenry55@uwo.ca)
University of Western Ontario

Co-Authors: Grahn, Jessica
University of Western Ontario

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”. Here, we were interested in the seemingly unique sensitivity humans show to temporal regularities in rhythm: they spontaneously feel a “beat” in rhythmic sequences. We examined how synchronization of neural oscillations with auditory rhythms might give rise to beat perception, and how entrained neural oscillations might affect psychophysical performance. In the current electroencephalography (EEG) study, participants detected targets embedded in simple or complex auditory rhythms. Simple rhythms induced a strong sense of a beat, whereas complex rhythms did not. We compared power at beat-related frequencies (1.25, 2.5, and 5 Hz, where 5-Hz was the base inter-tone interval) for simple and complex rhythms. Power was stronger at 1.25 Hz and 2.5 Hz for simple compared to complex rhythms, in particular for “good beat perceivers”, as determined by a behavioral measure of beat-tapping variability. This result indicates stronger subharmonic entrainment for rhythms that gave rise to a strong sense of beat. We did not observe power differences between rhythm types at 5 Hz. We also examined power-envelope fluctuations in the beta (13–30 Hz) frequency band, which have been previously linked to temporal prediction of events comprising isochronous sequences. Beta power fluctuations at 5 Hz were stronger for simple than for complex rhythms, suggesting that temporal prediction of upcoming events is sharpened in the presence of a strong beat percept. Target detection during listening to simple, but not complex, rhythms depended on an interaction between entrained neural phase and beta power.

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Motor system excitability dynamics during auditory anticipation and beat perception

Presenting Author: **Cameron, Daniel** (danielcameron01@gmail.com)
Brain and Mind Institute, University of Western Ontario

Co-Authors: Henry, Molly; Everling, Celina; Grahn, Jessica
Brain and Mind Institute, University of Western Ontario

Humans synchronize movements with the regular, perceived emphasis (the beat) in musical rhythms. Neural activity during beat perception is dynamic, time-locked, and heavily based in the motor system. In a previous study, motor system excitability (as indexed by motor-evoked potentials, or MEPs, elicited by transcranial magnetic stimulation, or TMS) was greater when listeners heard rhythms with a strong beat vs. a weak beat, but only for MEPs elicited 100 ms before the beat, not for MEPs elicited at random time positions. Thus, motor system excitability may fluctuate during beat perception.

In two experiments, participants listened to either 1) isochronous (at three rates: 200 ms, 550 ms, 900 ms) and jittered tone sequences, or 2) non-isochronous auditory rhythms (with three different levels of beat strength: strong beat, weak beat, and non-beat). TMS was applied to left primary motor cortex at evenly spaced time points in the 1) inter-tone interval, or 2) inter-beat interval of each type of rhythm. MEP amplitudes were recorded with electromyography from the right hand (first dorsal interosseous muscle), allowing assessment of excitability dynamics with respect to regularities in the auditory rhythms.

MEPs evoked during listening to isochronous auditory rhythms were best fit by sinusoidal functions that matched the rate of auditory stimulation (vs. sinusoidal functions at unrelated rates). Thus, motor system excitability fluctuated at the specific rates of the isochronous rhythms. During beat perception (during listening to strong beat but not weak beat or non-beat rhythms), excitability increased linearly over the beat interval, and the phase of beat rate fluctuations was consistent across individual listeners. Additionally, beat rate fluctuations were greater during listening to strong beat vs. weak beat and non-beat rhythms.

These results suggest that during listening to auditory rhythms, motor system excitability fluctuations synchronize to regularities, consistent with motor system functions in timing and rhythm perception.

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The Development of Beat Processing in Children

Presenting Author: **Hannon, Erin** (erin.hannon@unlv.edu)
University of Nevada, Las Vegas

Co-Authors: Nave-Blodgett, Jessica E., Nave, Karli M., and Snyder, Joel S.
University of Nevada, Las Vegas

Music listening entails perceptually organizing rich, multimodal temporal patterns. Western music typically induces an underlying beat (series of quasi-isochronous, periodic events), which is thought to be organized as a metrical hierarchy of stronger (downbeat) and weaker (upbeat) events. Prior research suggests that humans are sensitive to the beat (and possibly meter) as early as infancy, but it unclear when adult-like awareness of beat and hierarchical metrical structures develops. We used two behavioral tasks to examine development of beat and meter perception. In one, children (4-9 years) and adults (18+ years) heard a musical excerpt that strongly supported one of two possible beat patterns, followed immediately by an ambiguous rhythm that was consistent with either pattern. After this period of exposure to the ambiguous rhythm, which varied from 0-14 seconds, listeners heard a probe that was consistent with one of the two beat patterns and indicated whether the probe did or did not match the beat. Regardless of the length of the ambiguous phase, the younger children (4-7) did not perform significantly above chance, whereas the oldest children (age 8-9) and adults accurately matched the probe to the previously induced beat. In a second task, young children (5-10 years), adolescents (11-17 years), and young adults (18+ years) heard metronomes that matched or mismatched two levels of meter (beat and measure) of human-performed music, and they provided goodness of fit ratings. Children (5-10) gave higher ratings to metronomes that matched at the beat level, but they did not differentiate between beat-matching metronomes that did or did not match at the measure level. Adolescents also used beat to distinguish metronomes, but only the oldest adolescents (15-17) and adults were sensitive to synchrony at both the beat and measure level simultaneously. Taken together, these results suggest that robust and internally sustained beat and meter perception is characterized by a protracted developmental trajectory that is not refined until later adolescence.

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Associate Professor

Presenting Author: **Snyder, Joel** (joel.snyder@unlv.edu)
UNLV

Co-Authors: Nave, Karli; Nave-Blodgett, Jessica; Hannon, Erin
UNLV

Synchronization to rhythmic stimuli is an everyday experience, whether it is exercising to the beat of music, dancing salsa, or rocking a baby to sleep. Commonly, humans synchronize their movements with the frequency of the beat (a quasi-isochronous pattern of prominent time points). In addition, Western music is thought to have a metrical hierarchy, which results in stronger (downbeat) and weaker (upbeat) events. Previous research has shown that the intended beat periodicity of a rhythmic stimulus can be observed in periodic neural activity, although the extent to which this reflects robust perception of musical meter is unknown. In Experiment 1, we used electroencephalography (EEG) to investigate whether steady state-evoked potentials (SS-EPs, the electrocortical activity from a population of neurons resonating at the frequency of a periodic stimulus) reflect beat perception when the physical information in the stimulus is ambiguous and supports two possible beat patterns. Participants listened to a musical excerpt that strongly supported a particular beat pattern (context), followed by an ambiguous rhythm consistent with either beat pattern (ambiguous phase). During the final probe phase, listeners indicated whether or not a superimposed drum matched the beat. We hypothesized that SS-EPs would have higher amplitudes at beat-related frequencies than at non-beat-related frequencies, specifically when participants accurately identified the matching probe. We observed high SS-EPs at both the frequencies supporting the stimulus and frequencies supporting the beat of the context. In Experiment 2, we investigated whether beta band activity is modulated by beat information. Using EEG, we measured cortical responses during a musical metronome task, during which participants were asked to indicate whether or not a metronome matched human-performed music. We probed listeners' sensitivity to metrical hierarchies by separately varying the match between the metronome and the music at the beat level, measure level, both, or neither. Beta activity appeared to be stronger when the metronome fully matched the music. Taken together, these two experiments shed light on encoding of musical beat and meter in the brain.

Session: Traditional paper

Reward, uncertainty, learning, and the ventrolateral prefrontal cortex

Presenting Author: **Rudebeck, Peter** (peter.rudebeck@mssm.edu)
Icahn School of Medicine at Mount Sinai

Co-Authors: Murray, Elisabeth A.
Icahn School of Medicine at Mount Sinai

To choose the most advantageous course of action in our daily lives, we need to be able to combine information about the desirability of a possible option, such as how valuable a particular food is to us, with the availability or certainty of receiving that option. Economists have long appreciated this aspect of decision-making. By combining the probability that a particular outcome can be obtained with the subjective value of that outcome, the expected value of a particular course of action can be estimated. This allows distinct options to be compared and the best course of action chosen. Although economic choices of this sort are reasonably well understood at the behavioral level, less is known about the brain areas necessary for processing these two aspects of valuation. Both orbitofrontal (OFC) and ventrolateral prefrontal cortex (VLPFC) have been implicated in these decision processes, but their precise roles have remained unclear. Here we trained macaques with bilateral excitotoxic lesions of OFC, VLPFC, and unoperated controls on two tasks; the first assessed how monkeys use information about outcome availability to guide choices, whereas the second assessed how monkeys use information about outcome desirability to guide choices. We found that VLPFC, but not OFC, was critical for choices based on the certainty of receiving an outcome. By contrast, OFC, but not VLPFC, was critical for choices based on outcome desirability. Thus, separate parts of ventral prefrontal cortex in primates represent the desirability and certainty of receiving different potential outcomes, both of which are critical for deciding advantageously

Session: Traditional paper

Common circuits support frequency perception by audition and touch

Presenting Author: **Yau, Jeffrey** (jeffrey.yau@bcm.edu)
Baylor College of Medicine

Co-Authors:
Baylor College of Medicine

We perceive temporal frequency information by touch and audition. Although these senses have traditionally been studied separately, recent evidence from behavioral, neurophysiological, and neuroimaging studies suggest that touch and audition are closely linked. In this talk I will review how frequency information processing is similar in touch and audition, and how these senses exhibit highly specific perceptual interactions in the frequency domain – These findings suggest auditory and tactile frequency processing rely on related or common neural circuits. I will then describe the results from recent psychophysical, neuroimaging, and neuromodulation experiments that provide evidence of common neural mechanisms and overlapping auditory and tactile cortical frequency representations in human sensory cortex. Shared or supramodal neural circuits may support processing for multiple sensory modalities in a variety of perceptual domains.

Session: Traditional paper

Unpacking cognitive deficits in ASD via the motor system

Presenting Author: **Ewen, Joshua** (ewen@kennedykrieger.org)
Kennedy Krieger Institute/Johns Hopkins Medicine

Co-Authors: Pillai, Ajay; McAuliffe, Danielle; Mostofsky, Stewart
Kennedy Krieger Institute/Johns Hopkins Medicine

Autism spectrum disorders (ASD) are defined by deficits in social communication and by repetitive movements and restricted interests. These behavioral phenomena, however, are challenging to study in an experimental context. Motor atypicalities were noted in Kanner's original description; because motor behaviors are simpler to quantify than social-communicative behaviors, and because the brain networks for particular motor abilities have been well mapped, the motor system serves as lens through which to investigate fundamental cognitive deficits in ASD. In particular, there is a consistent relationship between praxis and gesture imitation on one hand and social-communicative competence on the other. We present the results of three studies. The first examines altered brain physiology, using EEG, in the context of praxis performance and reveals alterations of local and long-range cerebral connectivity in patterns that were unanticipated. The second examines, behaviorally, abnormalities of novel gesture skill learning. In two independent samples, we found that children with ASD take longer to learn to imitate novel, meaningless gestures. The third study examines, in two independent samples, a specific task parameter that separates relatively preserved from relatively impaired gesture imitation function in ASD. Specifically, children with ASD have a significantly higher performance cost when the gesture to be imitated requires the simultaneous performance of two gesture elements. Taken together, these studies bear upon theoretical accounts of ASD and suggest underlying cognitive limitations that may result in altered motor and social-communicative skill performance.

Session: Work in progress

Mouse models of ASD: Social/communicative deficits and “splinter” acoustic skills

Presenting Author: **Fitch, Holly** (roslyn.h.fitch@uconn.edu)
University of Connecticut

Co-Authors: Rendall, Amanda; Perrino, Peter
University of Connecticut

Despite profound anomalies and impairments associated with ASD, low-level perceptual enhancements in “local” auditory and visual processing are also reported. Moreover, these enhancements are most often seen in the same subset of ASD individuals that show concurrent speech delays/impairments. Although transgenic mouse models have been used successfully to model atypical social and repetitive behaviors in mice, enhancements in low-level sensory processing have never (to our knowledge) been reported. We assessed transgenic mouse models for two different ASD risk genes (CNTNAP2 knock-out and CACNA1C point-mutation knock-in). In addition to replicating social deficits and repetitive behavioral phenotypes, we also found an unexpected enhancement in frequency discrimination in both models. If we could learn how disruption of these very different genes leads to anomalies in brain development and circuitry associated with enhanced low-level auditory perception, it would improve our understanding the developmental cascade underlying atypical language outcomes in ASD.

Session: Work in progress

A cross-species examination of the substantia nigra in prepulse inhibition

Presenting Author: **Forcelli, Patrick** (paf22@georgetown.edu)
Georgetown University, Dept of Pharmacology and Physiology, Dept of Neuroscience, Interdisciplinary Program in Neuroscience

Co-Authors: Aguilar, Brittany; Malkova, Ludise
Georgetown University, Dept of Pharmacology and Physiology and Interdisciplinary Program in Neuroscience

Prepulse inhibition (PPI) is an operational measure of sensorimotor gating, which is altered in patients with schizophrenia and other neuropsychiatric illnesses. Two regions implicated in this behavior are the substantia nigra pars reticulata (SNpr) and the superior colliculus (SC). The pathway projecting from SNpr to SC is GABAergic: SNpr tonically inhibits the SC. While lesion studies have shown components of this pathway to be engaged in PPI, relatively little exploration of this circuit has been performed. While the basic organization of the basal ganglia and nigrotectal projections are highly conserved across phylogeny, recent studies from our group have divergent functional topography between rat and macaque SNpr and SC. However, the degree to which this circuit mediates PPI in rats and monkeys is unknown. Thus, our goal was to evaluate (1) the effect of focal inhibition of the SNpr on PPI in both macaques and rats and (2) the contribution of direct projections from the SNpr to the SC using optogenetic methodologies in rats. For Exp 1, we employed intranigral microinjection of the GABA receptor agonist muscimol in freely moving macaques and conducted parallel experiments in rodents. PPI was measured using a whole-body startle apparatus. Consistent with prior lesion studies in rodents, inhibition of the SNpr impaired prepulse inhibition in rats injected with muscimol. Much to our surprise, when macaques were infused with muscimol we found a striking enhancement of prepulse inhibition. This enhancement was evident at all prepulse intensities when compared to sham/saline microinjection sessions. These data suggest a surprising dissociation in this highly conserved gating mechanism between species. For Exp 2 we employed optogenetic inhibition of nigrotectal projections (i.e., GABAergic terminals in the SC originating in neurons from the SNpr) in rats. When nigrotectal terminals within the SC were ontogenetically silenced, a significant disruption in PPI was detected. These data suggest that the disruption of PPI caused by nigral inhibition in the rat may be mediated through disinhibition of the SC. These data underscore the importance of cross-species validation of circuitry.

Session: Work in progress

Cerebellar contributions to sequence detection in verbal working memory

Presenting Author: **Peterburs, Jutta** (jutta.peterburs@uni-muenster.de)
Department of Neurology, Division of Cognitive Neuroscience, Johns Hopkins University School of Medicine, Baltimore, MD

Co-Authors: Desmond, John E.
Department of Neurology, Division of Cognitive Neuroscience, Johns Hopkins University School of Medicine, Baltimore, MD

Cerebellar activations are often observed in non-motor, cognitive tasks involving linguistic and executive functions, and have inspired several different theories of the basic functions provided by the cerebellum which may include specific functions such as timing or sequence (deviation) detection, and more general functions such as monitoring and internal modeling/error correction. In the present study, we aim to investigate cerebellar contributions to sequence deviation detection in verbal working memory. To this end, subjects perform an fMRI-adaptation of the Sternberg task in which stimuli are arrays of phonologically similar (e.g., DCTZBV) or dissimilar consonants (FJQHNR) with either high (6 consonants) or low (2 consonants) load that contain a repeating sequence of three consonants (e.g., CTZ or FJQ) in half of the trials. The sequence deviation detection theory of cerebellar function would postulate that similarity of the phonemes makes sequence deviation detection a more difficult problem. However, the difficulty would be reduced if repeating sequences of letters were embedded into the array of letters to keep in mind. We hypothesize that the predictability of repeating sequences will lead to reduced error correction (consistent also with the forward model theory of the cerebellum), and thus reduced cerebellar activations. We further predict that the reduction of activation for repeating sequences will be more
pronounced for phonologically similar than for dissimilar letters. In this work in progress talk I am going to present some brandnew data and preliminary analyses.

Session: Symposium - Neuroscience of Social and Emotional Abilities

The Role of the Neuropeptide Oxytocin in Social-Cognitive and Affective Aging

Presenting Author: **Ebner, Natalie** (natalie.ebner@ufl.edu)
University of Florida

Co-Authors:
University of Florida

The oxytocin system is involved in social cognition and affective responding. Currently it is unknown whether effects of oxytocin on social-cognitive and affective capacities change with age. Our data provides first support of adult age differences in the function of oxytocin on resting-state connectivity among regions of the social and affective brain as well as on perceptions of trustworthiness and meta-mood.

Session: Symposium - Neuroscience of Social and Emotional Abilities

Learning about trustworthiness with age

Presenting Author: **Gutchess, Angela** (gutchess@brandeis.edu)
Brandeis University

Co-Authors: Rasmussen, Eileen
Brandeis University

The literature on how aging affects trust is relatively limited. Previous research has indicated that although cognitive functions decline in older adulthood, socio-emotional processes are maintained, or even given preferential attention. These diverging trajectories could suggest that the propensity to trust social others may increase with age, while learning to trust based on the financial behavior of others, posited to rely on more cognitive processing, may result in less adaptive investment behaviors in older compared to younger adults. 30 young adults and 30 older adults completed a survey measuring trust for others and trustworthiness of self, then completed an investment task with good, neutral, and bad brokers over three blocks. Our results indicate that age groups differ in their ability to learn who to trust. Older adult investment patterns suggested cognitive decline, in that older adults learned to distinguish the different broker types less well than younger adults. Although previous studies have mixed results connecting generalized trust measured by survey to behavioral trust measured in trust games or investment tasks, our results support a possible link, especially in regards to aging. We will discuss these results in relation to neural changes with age.

Session: Symposium - Neuroscience of Social and Emotional Abilities

Age and executive ability impact neural connectivity during race perception

Presenting Author: **Krendl, Anne** (akrendl@indiana.edu)
Indiana University

Co-Authors: Cassidy, Brittany
Indiana University

A growing body of work has shown that cognitive ability declines among older adults A growing body of work has shown that cognitive ability declines among older adults predicts their increased racial prejudice. We used functional magnetic resonance imaging (fMRI) to determine how declines in cognitive ability exacerbate older adults' expression of racial bias. In Study 1, young and older adults completed measures of their cognitive ability and racial bias. We replicated prior work showing that older adults with relatively impaired cognitive ability had greater racial bias than older adults with relatively preserved cognitive ability. In Study 2, young and older adults evaluated images of Black and White faces while undergoing fMRI. We found age effects in the dorsolateral prefrontal cortex (dlPFC)– a region previously implicated in maintaining a regulatory response. Specifically, we found that young adults had greater activity in the dlPFC than did older adults when they evaluated faces of Black versus White individuals. Importantly, cognitive ability decline was associated with reduced connectivity between the affective and cognitive regions associated with successful emotion regulation (amygdala and ventrolateral prefrontal cortex, respectively) when participants evaluated faces of Black (versus White) individuals. Specifically, older adults with relatively impaired cognitive ability (but not young adults or older adults with relatively preserved cognitive ability) had an increased affective response (in the amygdala) when they evaluated Black versus White faces. Moreover, young and older adults with relatively preserved cognitive abilities had stronger connectivity between neural regions associated with successful emotion regulation (ventrolateral prefrontal cortex) and the amygdala when they evaluated Black versus White faces. This was not the case for older adults with relatively impaired cognitive ability. These findings suggest that declines in cognitive ability may exacerbate racial bias by disrupting the interaction between affective and cognitive regions.

Session: Symposium - Neuroscience of Social and Emotional Abilities

Lifetime social and affective consequences of neonatal damage to the amygdala or hippocampus in rhesus macaques

Presenting Author: **Bliss-Moreau, Eliza** (eblissmoreau@ucdavis.edu)
University of California, Davis

Co-Authors:
University of California, Davis

The amygdala has long been implicated as a critical structure for normal affective and social processing in both humans and nonhuman animals. Despite a wealth of information on the role of the amygdala in adults, less is known about its importance for the development of normal affective and social behavior. To investigate its role in development, we studied the affective and social lives of a cohort of rhesus macaques (Macaca mulatta) who received neurotoxic lesions of the amygdala or hippocampus (an operated control group), or sham surgeries at two weeks of age and were subsequently raised with their mothers in small social groups. We studied their affective and social behavior from birth until twelve years of age (equivalent to 45-50 human years). All animals developed species-typical affective and social behavior repertoires. Compared to control and hippocampus-lesioned animals, amygdala-lesioned animals' behavioral responses to affectively valued (positive, negative, novel) stimuli were consistently blunted across their lives. During middle age, however, they were able to learn the affective value of stimuli via associative mechanisms – a capacity thought to require the amygdala. Unlike patterns of affective behavior, patterns of social behavior changed over time for both lesion groups. Early in development, amygdala-lesioned animals generated more frequent social signals than their peers; their social behavior essentially normalized over time. Hippocampus-lesioned animals became more social across development such that they initiated more frequent social interactions and spent more time engaged socially as adults than other animals. Results and implications of early damage will be discussed in context of histological and imaging studies which provide evidence of significant neural reorganization the brains of the lesioned animals.

Session: Symposium - Neuroscience of Social and Emotional Abilities

On the role of the nonhuman primate research in the study of social and emotional behavior

Presenting Author: **Malkova, Ludise** (malkoval@georgetown.edu)
Georgetown University Medical Center

Co-Authors:
Georgetown University Medical Center

With the advancement of modern imaging techniques, many questions about neural substrates of social and emotional behavior can be addressed in human patients and control subjects to the extent that was impossible decades ago. Nevertheless, animal models and especially nonhuman primate models still have their unique position in complementing research in humans in addressing questions about both the neurobiology of normal behavior and pathological conditions. More than hundred years of experimentation in nonhuman primates identified structures essential for social interactions, including the amygdala and prefrontal cortex, mostly based on lesioning techniques. In addition to this approach, still valid for answering specific questions, introduction of new techniques can advance our knowledge about specific receptors, the effects of activation (not just inhibition) of specific brain areas, and neuronal activity underlying complex behaviors. The most recent advancement in optogenetic and chemogenetic manipulations applied to nonhuman primate research opens a new promising direction with potential translational value for the treatment of pathological conditions in humans. The role of nonhuman primate research in complementing research in human subjects will be discussed.

Session: Traditional paper

Cognitive Challenge and the Aging Brain: Functional Alterations

Presenting Author: **Kennedy, Kristen** (kristen.kennedy1@utdallas.edu)
University of Texas at Dallas

Co-Authors: Rodrigue, Karen
University of Texas at Dallas

The aging brain undergoes functional and structural alterations as we age. Some of these changes are in the service of better performance while others are detrimental. Here we examine across two fMRI tasks in the same individuals how functional activation is modulated to parametric difficulty load in an adult lifespan sample (aged 20-94). We find sets of brain regions that up-modulate and down-modulate to difficulty. With increasing age, both sets of regions weaken in their modulation. Modulation of these regions is significantly coupled, interestingly in different ways on the two tasks, and these effects are discussed in regard to the DECHA model (Turner & Spreng, 2015). Further, reduced modulation with age was significantly associated with poorer performance on both the in-scanner task performance, and with relevant cognitive performance on neuropsychological assessment measures.

Session: Traditional paper

The distillation of memory and altered brain network dynamics in older adulthood

Presenting Author: **Turner, Gary R.** (grturner.ca@gmail.com)
York University

Co-Authors: Spreng, R. Nathan
York University

Knowledge of oneself and the world accumulates and becomes increasingly semanticized across the adult lifespan. This expanding repertoire of semantic knowledge provides a stable, distilled record of one's past that can be readily accessed and retrieved in the service of ongoing thought and action. At the same time, fluid cognitive abilities necessary to reconstruct and retrieve more detailed accounts of past experiences show marked decline with age. This shift in cognitive architecture, towards reliance on more semanticized recollection has a profound effect on decision-making capacity and problem-solving abilities in older adulthood. Yet the neural mechanisms of this altered recollective experience remain underspecified. We provide evidence that changes in brain network dynamics, specifically greater coupling of executive control and default network brain regions, reliably predict this age-related shift towards more semanticized recollection. We assessed autobiographical memory in a sample of younger (N=103) and older (N=80) adults. As predicted, reminiscence was more semanticized in the older cohort. Older adults retold personal episodes in less vivid detail, and included more fact-based and personal semantic information than the young. Critically, semanticized recollection was associated with greater default to executive network coupling in older adults. These findings demonstrate that age-related changes in brain network dynamics are associated with a qualitative shift in recollective experience, from detailed to increasingly distilled remembrances of one's personal past.

Session: Traditional paper

Individual differences in memory and brain aging

Presenting Author: **Hayes, Scott** (smhayes@bu.edu)
VA Boston Healthcare System; Boston University School of Medicine

Co-Authors: Hayes, Jasmeet; Williams, Victoria; Salat, David; Verfaellie, Mieke
VA Boston Healthcare System; Boston University School of Medicine

Aging is associated with pervasive cognitive and neural decline, yet there are remarkable individual differences in markers of cognitive and brain aging among older adults. Cardiorespiratory fitness, which can be improved with moderate to vigorous physical activity, is one factor that may contribute to individual differences in memory, brain structure, and brain function. To examine this issue, young and older adults completed comprehensive neuropsychological testing with an emphasis on memory and executive function, a progressive maximal exercise test on a treadmill to assess cardiorespiratory fitness, and magnetic resonance imaging (MRI) to assess brain structure and function. Our results showed that cardiorespiratory fitness was positively associated with episodic memory performance among older adults, but not younger adults. Further, among older adults, cardiorespiratory fitness was positively correlated with fractional anisotropy (an indicator of white matter integrity), cortical thickness, and task-related fMRI activation. In some cases, high fit older adults exhibited similar structural metrics as young adults, with age differences being driven by the low fit older adults (young adults = high fit older adults, with both groups > low fit older adults). In other cases, a step-wise pattern was observed (young adults > high fit older adults > low fit older adults). Overall, these results suggest that cardiorespiratory fitness may contribute to neuroplasticity among older adults, consistent with the brain maintenance hypothesis.

Session: Traditional paper

Laws of attraction: the innate lure of the proximal and the salient in ventral striatum

Presenting Author: **Morrison, Sara** (sara.morrison@pitt.edu)
Department of Neuroscience, University of Pittsburgh

Co-Authors:
Department of Neuroscience, University of Pittsburgh

Environmental stimuli that are associated with rewards, including food and drugs, can exert a powerful influence over behavior. Ordinarily this response is adaptive, helping organisms to track motivationally relevant stimuli and take appropriate action to obtain reward when it becomes available. However, reward-associated cues – e.g., the sight of drug paraphernalia – can also elicit approach or interaction even when such behavior is maladaptive. Many factors may influence this type of behavior, including features of the reward itself – e.g., reward magnitude, probability, and context-dependent desirability – and features of the cue, such as its salience and spatial proximity. Moreover, people and animals vary widely in their propensity to attribute motivational properties to cues, and this individual variation can be important in, e.g., determining whether a recovering addict will relapse.

In this talk, I will present evidence that all of these factors – including variation among individuals – are integrated by neural activity in the ventral striatum, which then acts to promote and invigorate approach towards reward-associated stimuli. The ventral striatum – particularly the nucleus accumbens core (NAcc) – has often been described as a "limbic-motor" interface, implying that this area integrates the value of expected rewards with the motor planning required to obtain them. Surprisingly, however, there has been little direct evidence that the signaling of NAcc neurons combines information about the predicted reward and the corresponding behavioral response. Drawing upon findings from behaviors ranging from sign tracking (a classic way to model individuals' tendency towards Pavlovian conditioned approach), to a simple operant task, to a complex multi-factor decision-making task, I will demonstrate that cue-evoked signals in the rodent NAcc can act as a physiological substrate for its limbic-motor integration functions. Acting over a relatively long time scale, NAcc activity (including, notably, inhibition of firing) provides a mechanism for linking reward prediction and other motivationally relevant factors, such as spatial proximity, to the probability and vigor of a reward-seeking behavioral response.

Session: Traditional paper

Damage to the ventromedial prefrontal cortex impairs memory integration

Presenting Author: **Race, Elizabeth** (elizabeth.race@tufts.edu)
Tufts University

Co-Authors: Tobin, Hope; Verfaellie, Mieke
Tufts University

The ability to integrate novel information with stored knowledge (schemas) can facilitate both long-term memory (LTM) and short-term memory (STM). Prior research suggests that the schematic facilitation of LTM relies on a circuit that involves both the hippocampus and ventromedial prefrontal cortex (vmPFC) (Schlichting & Preston, 2015). However, we recently demonstrated that the schematic facilitation of STM does not depend on the hippocampus (Race et al., 2015). The current study was designed to investigate whether the schematic facilitation of STM instead depends on the vmPFC, and if so, to elucidate the role of this region. One possibility is that vmPFC supports schema reinstatement or representation (Ghosh et al., 2014). Alternatively, vmPFC may support the integration of to-be-remembered information with activated schema representations (Spalding et al., 2015). To investigate these possibilities, patients with lesions to vmPFC and healthy controls performed two tasks that examined schema representation and memory integration, respectively. In the schema representation task, participants entered digits as quickly as possible into a keypad that either had a familiar keypad layout (e.g., an established visuospatial schema) or an unfamiliar layout (e.g., lacked an established visuospatial schema). In the STM-LTM integration task, participants viewed sets of digits presented in either the familiar or unfamiliar keypad layouts and performed an immediate digit recall task. Patients demonstrated a familiar keypad advantage of the same magnitude as controls in the schema representation task, but not in the memory integration task. These results reveal that the vmPFC plays a critical role in STM-LTM integration, but not in schema representation.

Session: Traditional paper

Neural convergence of perceptual and conceptual information

Presenting Author: **Barense, Morgan** (barense@psych.utoronto.ca)
University of Toronto

Co-Authors: Chris Martin
University of Toronto

In what way are the conceptual representations of real-world objects related to the visual perception of those objects? Although there is great interest in understanding the visual basis of conceptual knowledge, the inherent association between the visual and semantic properties of real-world objects presents a challenge when attempting to isolate how the brain represents either attribute. For example, a lion and a tiger are both large jungle cats, and so would be expected to share close quarters in semantic space; however, they also share numerous perceptual features with one another, including sharp teeth, forward facing ears, fur, and overall shape. In this way, visual and conceptual attributes are often confounded. The importance of this point is underscored by a substantial body of research that implicates the anterior temporal lobes, in particular the perirhinal cortex (PRC), in both conceptual and perceptual processing – but in these studies conceptual and perceptual features were not independent. In the current study, however, we independently varied conceptual and perceptual overlap across a set of objects. Using data from 2,785 participants, we generated behaviour-based models that captured the conceptual and perceptual similarities among the objects. We then compared these behaviour-based models of conceptual and perceptual object similarity to corresponding measures of neural similarity while a different group of participants completed property verification tasks that encouraged either conceptual or perceptual processing of the 40 objects. Using representational similarity analysis of fMRI data we found that the PRC was the only region in the ventral visual stream to show sensitivity to conceptual and perceptual object information – an effect that was observed regardless of whether the property verification task was conceptual or perceptual in nature. These results suggest that conceptual and perceptual object information converge in the brain, likely at the level of the perirhinal cortex.

Session: Traditional Paper

Targeted Metabolomics for Preclinical Alzheimer's Disease and Successful Cognitive Aging

Presenting Author: **Mapstone, Mark** (mark.mapstone@uci.edu)
Department of Neurology, University of California, Irvine

As the world population ages, primary prevention of age-related cognitive decline and disability will become increasingly important. Prevention strategies for cognitive decline are often developed from the perspective of disease pathobiology, but models of biological success may also provide additional insights. Our group has focused on developing easily accessible, inexpensive, and accurate biomarkers of cognitive health and disease which may inform our understanding of divergent cognitive trajectories. In this talk, I will present our metabolomics findings obtained during the longitudinal study of more than 525 older adults over the age of 75. We classified participants based on cognitive status at the beginning of the study and at each visit for up to five years. Some of the participants entered the study with impaired cognition consistent with mild cognitive impairment (MCI) or AD (n=74), some transitioned from a cognitively normal state to cognitively impaired over the course of the study (n=28), others remained cognitively normative (n=210), and still others showed superior cognitive abilities (n=42). Quantification of metabolites obtained from plasma allowed us to develop biomarker panels which accurately identified the cognitively defined groups with very high accuracy (receiver operating characteristic area under the curve of >0.90). Metabolites in the biomarker panels primarily included phospholipids and amino acids implicated in key metabolic pathways regulating cell membrane integrity, oxidative stress, inflammation, and nitric oxide bioavailability. These findings from across the cognitive continuum highlight the dynamic interplay of these pathways in normative and even successful cognitive aging and whose failure may contribute to age-related memory impairment.

Session: Work in progress

How Does Scrabble© Expertise Alter Age-Related Multiscale Changes in Brain Signal Variability?

Presenting Author: **Protzner, Andrea** (protzner@ucalgary.ca)
University of Calgary

Co-Authors: Wang, Hongye; Cortese, Filomeno; Pexman, Penny
University of Calgary

We examined the interplay between healthy brain ageing and long-term visual word recognition practice in the context of tournament Scrabble training. We measured EEG while Scrabble experts and controls performed an expertise-related task (lexical decision task: is it a word?) and a non-expertise-related task (symbol decision task: do any symbols match?). We quantified brain signal variability with multiscale entropy (MSE), a measure that is sensitive to linear and nonlinear variability, and can differentiate variability of a complex system (e.g., the brain) from a purely random system. Consistent with previous ageing research, we found an age-related increase in short-range neural communication, or fine-scale MSE, in both experts and controls ($p < .001$). In addition, we found a robust expertise effect on brain ageing at middle temporal scales during both tasks, where mid-scale MSE increased in experts but decreased in controls ($p < .001$). This result suggests that longer-range neural communication was maintained through older age for experts but not for controls. Interestingly, expertise-related brain changes did not lead to improved performance, as these MSE effects were associated with slower response times on both expertise- and non-expertise-related tasks ($p < .001$).

Session: Work in progress

Preferential viewing of old scenes reflects conscious memory for which scenes are old or new

Presenting Author: **Smith, Christine** (cnsmith@ucsd.edu)
Veterans Affairs Healthcare System; University of California San Diego

Co-Authors: Urgolites, Zhisen; Squire, Larry
Veterans Affairs Healthcare System; University of California San Diego

When individuals try to select the recently studied (and familiar) item during a multiple-choice memory test, they direct a greater proportion of viewing time at the selected item when the choice is correct than when the choice is incorrect. Thus, for both correct and incorrect choices, individuals believe that the chosen item is old, but viewing time can differentiate between old and new items. What kind of memory supports this preferential viewing effect? One possibility is that automatic, hippocampus-independent memory processes support this effect because viewing time can differentiate old items from new items independently of overt behavioral choice. Alternatively, conscious, hippocampus-dependent memory processes might support this effect. If so, size of the preferential viewing effect should be related to established measures of declarative memory (i.e., accuracy scores, confidence ratings, and response times). We examined eye movements while young adults (N=30) made three-alternative, forced choice, recognition memory judgments for targets (200 photographs of scenes studied 30 min earlier) versus foils (two novel scenes that were similar to the target). We replicated the preferential viewing effect. Importantly, the size of the effect was correlated with overall accuracy scores, as well as with the difference in confidence ratings and the difference in response times for selected targets versus selected foils. Thus, when individuals look longer at the chosen item when it is correct than when it is incorrect this effect reflects conscious memory for which items are old and which items are new.

Session: Work in progress

Investigating the role of the cerebellum in motor, linguistic, and social prediction

Presenting Author: **Stoodley, Catherine** (stoodley@american.edu)
American University

Co-Authors: Martin, Stephanie; Drury, Brianne; Thomas, Christina; D'Mello, Anila
American University

Clinical, neuroanatomical, and neuroimaging data suggest that the human cerebellum is involved in cognitive and social processing as well as motor control. That said, the precise contribution of the cerebellum to such diverse tasks is not known. It has been proposed that the cerebellum builds internal models that are used to optimize performance, and that these internal models can be used to predict upcoming stimuli, leading to improved accuracy and faster response times. Here, we use cerebellar neuromodulation (transcranial direct current stimulation [tDCS]) and functional MRI to test the hypothesis that the cerebellum is involved in prediction during motor, language, and social tasks. Each task contains trials in which responses can be predicted from the task context, and other trials in which the responses are unpredictable. Thus far, 22 healthy young adults (20.3 ± 1.8 years old) have completed a behavioral study examining the effects of anodal, cathodal, and sham tDCS over the right posterolateral cerebellum on predictive processing during motor, language, and social tasks. We have also used combined tDCS-fMRI in 32 young adults (23.1 ± 2.5 years old) to examine the role of the cerebellum in linguistic prediction. Finally, data from participants completing the motor, cognitive, and social prediction tasks in a within-subjects (anodal, cathodal, sham) tDCS-fMRI study will also be presented. This work-in-progress aims to answer the following questions: 1. Does cerebellar neuromodulation specifically impact performance during tasks taxing predictive processing? 2. How does the polarity of neuromodulation (anodal, cathodal) affect performance? and 3. What are the neural changes associated with cerebellar neuromodulation?

Session: Traditional paper

Structural variability across the primate brain and its relationship to evolution

Presenting Author: **Croxson, Paula** (paula.croxson@mssm.edu)
Icahn School of Medicine at Mount Sinai, New York

Co-Authors: Forkel, Stephanie; Cerliani, Leonardo; Thiebaut de Schotten, Michel
Icahn School of Medicine at Mount Sinai, New York

Evolution results from the balance of intraspecies variability and natural selection. A large amount of variability exists across human brains; revealed initially on a small scale by post mortem studies and, more recently, on a larger scale with the advent of neuroimaging. Here, using grey and white matter magnetic resonance imaging measures in humans and macaque monkeys, we showed a relationship between anatomical variability and evolutionary expansion maps of the primate brain. This suggests a relationship between low variability and evolutionary stability, while areas of high variability may have evolved more recently and be less similar across individuals. The monkey brain was overall structurally as variable as the human brain, but the human brain had an additional left hemispheric asymmetry in variability across several phylogenetically recent regions. Therefore, it may be that the same variability that makes us individually different from each other is also at the root of our differences from our ancestors and our closest evolutionary relatives. This suggests that cerebral variability may add another dimension to our understanding of evolutionary mechanisms.

Session: Traditional paper

The Cerebellum and Emotion

Presenting Author: **Marvel, Cherie** (cheriemarvel@gmail.com)
Johns Hopkins University

Co-Authors: Kronemer, Sharif; Onyike, Chiadi; Pietrowski, Jessica; Rosenthal, Liana
Johns Hopkins University

The cerebellum has long been associated with emotion control. In fact, pioneering research in the 1970s used chronic subdural cerebellar stimulation as a “brain pacemaker” to normalize behaviors of intractable patients with violent outbursts (Heath, 1977). More recently, cerebellar cognitive affective syndrome (CCAS) has been described in association with cerebellar disorders (Schmahmann, 1998). However, the association between the cerebellum and emotion has not been considered in mainstream science.

To examine the relation between the cerebellum and emotion, we assessed psychiatric symptoms in patients with spinocerebellar ataxia (SCA), a hereditary, neurodegenerative disorder of the cerebellum. We interviewed 20 patients and their spouse/close friend (“informant”) regarding changes in the patient’s mood since the onset of ataxia. Consensus ratings were conducted on all interviews by assessing symptom severity of the 12 psychiatric symptoms of the Neuropsychiatric Inventory Questionnaire (NPI-Q).

Even though 8 (40%) patients were on anti-depressants, depression and anxiety were reported in 70% and 80% of patients, respectively, endorsed by patients and informants. However, informants were more likely than patients to endorse “agitation/aggression” and “irritability/lability” in the patients. Measures of real-world fine motor skills (e.g., using utensils, buttoning buttons, writing with a pencil) and clinical measures (speech fluency and finger tapping speed) correlated with ratings of agitation/aggression, irritability/lability, and depression.

These data indicate that: 1) emotion control is impacted by cerebellar degeneration, 2) depression and anxiety are highly prevalent in SCA, 3) family members are more likely than patients to perceive certain mood changes, and 4) motor impairments track with mood severity. These findings highlight a need for clinician awareness of emotion dysregulation in SCA in order to improve treatment and patient/family education.

Session: Traditional paper

The hippocampus and mPFC in retrieval of vivid and vague memories

Presenting Author: **McAndrews, Mary Pat** (mp.mcandrews@uhnresearch.ca)
University Health Network

Co-Authors: McCormick, Cornelia; Sekeres, Melanie; Moscovitch, Morris
University Health Network

Some events can be recalled with rich perceptual detail, such that one can 're-experience' them, and others are vague and indistinct, with only the gist of the experience available. Considerable evidence suggests that the hippocampus (HC) plays a key role in recall for the former whereas the prefrontal cortex (vmPFC) may be more engaged for the latter, although recall in many circumstances may involve interplay between these and other structures. Here we present two neuroimaging studies, the first with healthy individuals who were exposed to complex events (novel movie clips) and then asked to recall the content one day and seven days afterward. We found that the mPFC became increasingly involved in retrieval over time whereas the HC engagement decreased. However for those memories that continued to show a high degree of perceptual vividness, HC was similarly active at recent and remote time points. The second study involves individuals with medial temporal lobe epilepsy (mTLE) and controls who were scanned while recalling autobiographical events from their personal past. In this study we focussed on differences between event construction (implicated in schematics or gist) and elaboration (associated with vividness), and anterior and posterior segments of the HC. The mTLE group showed greater activation in the mPFC whereas controls activated the HC during retrieval. Furthermore, controls showed differential connectivity amongst HC regions and between HC segments and mPFC during construction vs elaboration; mTLE patients instead showed static connectivity within the HC and more variable connectivity between mPFC and other neocortical regions during the phases of retrieval. Both studies underscore how different networks are associated with qualitatively different types of retrieved experience, in one case following time-dependent consolidation and in the other in association with medial temporal dysfunction.