First Author: Heather Acuff (Graduate)	Poster Session: am
Presenting Author: Heather Acuff (Graduate)	Location: 1
Mentor/Lab: Dr. Mary Phillips	Category: Imaging Techniques
Department: Psychiatry	

Title: Determining Relationships between White Matter Structure and Function in Offspring at Risk for Bipolar Disorder: The Bipolar Offspring Study

Summary: Bipolar Disorder is a serious psychiatric disorder that is difficult to distinguish from other psychiatric disorders particularly in children. We examined relationships between brain structure and function in order to identify relationships that distinguish children at risk for Bipolar Disorder compared to children at risk for other disorders. We found that the relationship between forceps minor structure and activity in the cingulate cortex significantly distinguishes these two groups and may be a marker of risk for developing Bipolar Disorder.

Abstract: Early detection of Bipolar Disorder (BD) risk is critical for targeting interventions to delay or prevent illness onset. Yet the absence of objective BD biomarkers makes accurately identifying at-risk youth difficult. Recent studies have identified abnormalities in white matter (WM) structure and activity in emotion processing neural circuitry in BD at-risk youth. We aimed to elucidate WM-activity relationships in BD at-risk youth and determine how they differentiated youth at genetic risk for BD from youth at risk for other disorders. Offspring (ages 8-17) of parents with BD (OBP n=32) and offspring of parents with non-BD disorders (OCP n=30) underwent diffusion tensor and functional magnetic resonance imaging while performing an emotional face processing task. Elastic net regression analyses included GROUP(OBPOCP)xWM interactions as main independent variables and emotion processing activity as dependent variables to determine significant group differences in WM-activity relationships. 14 variables explained 16.5% of the variance in amygdala and prefrontal cortical activity to happy faces including 8 GROUPxWM interactions. Significant group differences in slopes (inverse for OBP positive for OCP) were found for relationships between right cingulum length-caudal anterior cingulate activity ($p=0.024$) and forceps minor radial diffusivity-rostral anterior cingulate activity ($p=0.014$). Only the between-group difference in forceps minor-activity remained significant in unmedicated youth without psychiatric disorders ($p=0.017$). WM-activity relationships significantly distinguish BD at-risk youth from youth at risk for other disorders and may reflect vulnerability mechanisms predisposing to future BD and biomarkers to facilitate identification of BD at-risk youth.

First Author: Jamie Cohen (Graduate)	Poster Session: am
Presenting Author: Jamie Cohen (Graduate)	Location: 2
Mentor/Lab: Kirk Erickson	Category: Imaging Techniques
Department: Psychology	

Title: Cardiorespiratory Fitness and Brain Activity During a Stroop Task

Summary: Better cardiorespiratory fitness is associated with improved cognition and brain health in older adults and children so we sought to determine if this relationship exists in young adults. Smaller differences in brain activity during two conditions of an executive functioning task were associated with better cardiorespiratory fitness in multiple brain regions. These increases in neural efficiency related to fitness levels provide important evidence that the relationship between cardiorespiratory fitness and cognition exists across the lifespan.

Abstract: Better cardiorespiratory fitness (CRF) is associated with improved executive functioning (EF) in older adults and children. However few studies examine this relationship in younger adults. The variability in EF task performance is often limited in younger samples leading to fewer studies exploring its relationship with CRF. However it is an important link to establish as increasing exercise and physical health may improve cognitive functioning in the general population. Here we sought to determine if the relationship between CRF and EF exists throughout the lifespan. 50 young adults (age=25.22+5.17; 44% male) underwent a neuropsychological assessment neuroimaging and CRF testing. CRF testing included a quantification of maximal oxygen consumption (VO2max) that controlled for body mass (VO2max/kg). Participants completed a computerized Stroop task in a magnetic resonance scanner to obtain functional neuroimaging (fMRI). Lower-level contrasts compared the incongruent (INC) congruent (CON) and neutral (NEU) conditions of the Stroop task with a fixation and against each other. Higher-level analyses controlling for sex examined the whole-brain associations between VO2max/kg and BOLD activation. Paired-sample t-tests compared the mean percent signal change for the Stroop task conditions for each activation cluster. Comparing activation during INC and CON revealed bilateral clusters in the medial prefrontal cortex superior parietal cortex and right caudate nucleus that were negatively associated with VO2max/kg. In all cases smaller differences in activation between conditions was associated with higher CRF (all r(49)<-.423 all p<.002). Higher CRF was associated with increased neural efficiency in younger adults without cognitive deficits. Areas known to be susceptible to changes following increased exercise including the prefrontal cortex showed this increased CRF-related neural efficiency. These associations have not previously been demonstrated in younger adults and provide evidence that CRF is related to EF across the lifespan.

First Author: Sandip Panesar (Postdoctoral)	Poster Session: am
Presenting Author: Sandip Panesar (Faculty)	Location: 3
Mentor/Lab: Juan Fernandez-Miranda	Category: Imaging Techniques
Department: Neurological Surgery	

Title: High-Definition Fiber Tractography of Ventral External-Capsule White Matter

Summary: High definition fiber tractography is able to visualize white-matter pathways in living subjects. There is significant controversy pertaining to the structure and connectivity of two critical white-matter pathways (inferior fronto-occipital fasciculus and uncinate fasciculus). We have been able to consistently reproduce the aforementioned tracts in MRI scans of 30 single-subjects and have a template consisting of MRI data from 842 subjects averaged into one which we have used to validate our findings.

Abstract: High-definition fiber tractography (HDFT) is an in vivo imaging modality derived from diffusion-weighted magnetic resonance imaging (dwMRI) data. HDFT addresses a major limitation of diffusion tensor imaging (DTI) based tractography namely its inability to visualize areas of crossing white-matter fibers. Two important association fascicles traverse the ventral external capsule: Inferior fronto-occipital fasciculus (IFOF) and uncinate fasciculus (UF). These pathways are thought to play critical roles in language functions amongst other functions. Significant controversy exists in the literature regarding origins subdivisions and cortical terminations of both tracts. We conducted HDFT in 30 single subjects from the human connectome project and used a novel atlas consisting of averaged diffusion data from 842 individual subjects to verify our findings. We found distinct tripartite division of the IFOF with conserved bihemispheric volumetry. UF consisted of two components on the left however bipartite structure was inconsistently found on the right. As such left-hemispheric UF's demonstrated significantly greater volumetry compared to the right. Our findings were verified by the atlas. Our findings indicate that the IFOF may indeed play a role in language particularly semantic tasks and UF may play a role in both language and emotion.

First Author: Brett Bankson (Graduate)	Poster Session: am
Presenting Author: Brett Bankson (Graduate)	Location: 4
Mentor/Lab: Laboratory of Cognitive Neurodynamics Avniel Ghuman	Category: Imaging Techniques
Department: Psychology	

Title: Temporal Evolution of Abstract Visual Representations

Summary: Visual object recognition occurs rapidly in humans with perceptual and conceptual knowledge available in the first several hundred milliseconds of viewing an object. Novel analysis techniques allow us to view on a millisecond basis these patterns of neural activity from MEG data and make predictions about how temporal information evolves from purely visual to conceptual in nature. Using complex representational models derived from behavior and deep neural nets we plot the emergence of object concept representations that are behaviorally relevant and share information with other similar concepts.

Abstract: Object recognition in the human visual system is a dynamic process that evolves rapidly from representations of low-level visual features to behaviorally relevant concepts. Previous work characterizing the temporal progression of object representation has incorporated predictions from category structure semantic feature norms and fMRI-MEG fusion to identify recurrent processing stages during visual object recognition. We consolidate and resolve this previous work by comparing MEG signals from two independent data sets predictions from semantic and neural network models and behavior to elucidate the extent to which representational structure for object concepts can generalize across time and between exemplars. Critically the application of decoding methods and representational similarity analysis (RSA) to our data affords an unparalleled temporal resolution to the investigation of fine-grained representational structure inherent to patterns of neural activity during visual object recognition. Time course data from temporal decoding RSA and variance partitioning analyses show several latencies before 300 ms at which rapidly accessed perceptual and semantic features iteratively contribute complementary information to the emergence of abstracted conceptual representations for concrete objects. Together these methods and results highlight the emergence of conceptual representations for concrete objects within the first 250 ms of visual recognition.

First Author: Marc Coutanche (Faculty)	Poster Session: am
Presenting Author: Griffin Koch (Graduate)	Location: 5
Mentor/Lab: Marc Coutanche	Category: Imaging Techniques
Department: Psychology	
Title: Neural Correlates for Trait Memory Differences	
Summary: We used neuroimaging techniques to investigate brain regions involved in episodic and semantic memory. Additionally we compared the relative sizes of these regions with participants' memory characteristics (episodic or semantic).	

Abstract: Humans draw on an array of neural systems in the course of learning (and later remembering) the broad range of information encountered every day. Although healthy humans all have access to the same sets of brain systems there is evidence that people differ in the extent to which they draw on one type of memory versus another. Some individuals tend to emphasize the factual components of past events (semantic) while others are more biased to forming memories that are rich in spatiotemporal and contextual features (episodic). The current study investigated the neural basis for trait differences in the relative use of semantic episodic and spatial memory systems across individuals. We scanned the brains of 20 participants using magnetic resonance imaging (MRI) and related the volume of key brain regions and systems to scores on a survey of autobiographical memory which quantifies self-reported episodic semantic and spatial memory usage. We have found that brain regions associated with different memory systems differ in relative volume across individuals in ways that systematically track individual variation in trait memory biases. Our findings include the result that individuals with stronger semantic memory characteristics have a larger percentage of cortical gray matter occupied by the temporal poles and right angular gyrus. These anatomical findings contribute additional evidence to identifying the anterior temporal lobes and angular gyrus as "semantic hubs". More generally this study provides evidence that anatomical brain differences have a relationship with an individual’s memory characteristics.

First Author: Tristen Inagaki (Faculty)	Poster Session: am
Presenting Author: Lauren Ross (Graduate)	Location: 6
Mentor/Lab: Social Health Affective Neuroscience Lab	Category: Imaging Techniques
Department: Psychology	

Title: The Benefits of Giving Social Support: Giving Targeted and Untargeted Support

Summary: These studies examine the potential benefit of giving support to others. In study 1 giving targeted support (to an identifiable individual) resulted in increased septal area (SA) activity and was associated with decreased amygdala activity. In study 2 self-reports of giving targeted support were associated with less amygdala activity during an amygdala reactivity task.

Abstract: Giving support significantly contributes to the link between social ties and health. However the neural mechanisms linking the provision of support to health are not known. It has been suggested that giving support leads to benefits via neural regions implicated in parental care in animals. The current studies therefore assess the contribution of parental caregiving-related neural regions to giving support in humans and as a further theoretical test examine whether the benefits of giving targeted support to a single identifiable individual in need extends to giving untargeted support to larger societal causes. Study 1 (N = 45) demonstrates that giving targeted (vs. untargeted) support results in greater feelings of social connection and feelings that the support was effective. Further greater septal area (SA) activity one of the key regions involved in parental care in animals to giving targeted support is associated with less amygdala activity to social threat. However SA activity to giving untargeted support is not related to amygdala activity. Using a large independent neuroimaging sample Study 2 (n = 384) replicates and extends this second finding to show that self-reports of giving targeted support are associated with less amygdala activity to a different socially threatening task. Once again giving untargeted support is not related to amygdala activity. Results highlight the unique benefits of giving targeted support and elucidate neural pathways by which giving support may lead to health benefits.

First Author: Dylan Royston (Graduate)	Poster Session: am
Presenting Author: Dylan Royston (Graduate)	Location: 7
Mentor/Lab: Collinger	Category: Brain-Machine Interfaces
Department: Bioengineering	

Title: Investigating the effects of goal-directed sensory information on intracortical hand representations in human sensorimotor cortex

Summary: When we use our hands to interact with objects several brain areas are recruited to transform goal-related sensory information into effective movement plans. We are studying how the activity of neurons in human motor and somatosensory cortex change to encode simple vs goal-directed movements. Understanding how this activity reflects different kinds of object-related sensory information can help improve rehabilitation practices and further our understanding of complex brain functions.

Abstract: Intracortical brain-computer interfaces (BCI) can allow people with spinal cord injury (SCI) to control robotic limbs by translating neural activity recorded from microelectrode arrays in motor cortex (M1) into intended movements. This technology is based on research relating specific patterns of neural modulation to movement kinematics; however the M1 activity encoding hand grasping appears to change when different objects are presented even when the grasp kinematics remain the same. These results suggest that visuomotor transformations influence the activity in M1 but it remains unclear which visuomotor or contextual properties influence M1 activity independent of kinematics. Here we seek to investigate how visual auditory and somatosensory cues during attempted movements influence neural population activity by measuring intracortical neural activity from a person with tetraplegia. We are collecting intracortical recordings from two microelectrode arrays implanted in the primary motor (M1) cortex and two arrays implanted in the primary somatosensory (S1) cortex of a human participant with a C5-motor/C6-sensory incomplete SCI. Data are recorded while the participant views and attempts to perform rhythmic sensorimotor tasks with their right hand such as hand grasping and having their fingertips touched. Each task is presented with 4 levels of multimodal sensory information: simple (video of basic movement/sensation) goal (object-directed) audio (object-directed + auditory timing cue) and stim (object-directed + auditory cue + vibrotactile timing cue). For example a hand grasp task is presented as simple (a hand opening/closing) goal (a hand squeezing a ball) audio (a hand squeezing a ball + a chime at full closure) and stim (a hand squeezing a ball + a chime + vibration at full closure). To determine how sensorimotor encoding is affected by task context we will analyze changes in both single-unit encoding and population-level representations. Single-unit encoding will be quantified by performing Fourier transforms on each unit's time-series activity and determining the amplitude of the peak spectral power at frequencies matching the kinematic pacing of the tasks. Population-level representations will be quantified by using principal component analysis (PCA) to determine the similarity between the population-wide patterns of activity representing each movement. By comparing the activity encoding each movement across different levels of sensory enrichment as well as the effects of this enrichment on neural activity recorded from different areas of cortex we can determine how a task's context alters how it is encoded in cortical hand representations. These analyses will help determine how goal-directed sensory information shapes the neural representation of intended hand movements in sensorimotor cortex informing our understanding of sensorimotor integration and providing a potential avenue for improving the utility of intracortical BCI systems.

First Author: Ahmed Jorge (Graduate)	Poster Session: am
Presenting Author: Ahmed Jorge (Graduate)	Location: 8
Mentor/Lab: Jennifer Collinger	Category: Brain-Machine Interfaces
Department: Neurosurgery Physical Medicine and Rehabilitation	

Title: The Use of a Finger Exoskeleton and an Intracortical BCI in Patients Suffering from a Stroke

Summary: Many people that have suffered a stroke have problems moving their fingers. Unfortunately our current therapies for helping them are still lacking. We believe; however that a brain computer interface and an external finger robot could help these patients get back some of their ability to move their fingers.

Abstract: Stroke is the third most common cause of morbidity (4%) and the second most common cause of mortality (10%) worldwide. Despite this pronounced incidence therapies for upper limb weakness and paralysis are still limited in scope and outcomes and do not address the needs of individuals with severe and chronic weakness specifically in regards to their fingers. Conventional robotic therapy can provide individuals that have suffered a stroke with repetitive physical therapy with hopes of regaining function. It also facilitates movements that the patient would not be able to achieve otherwise. Nonetheless blind repetitive motion can impact a patient's behavior during therapy and thus affect the motor plasticity rehabilitation process. In addition robotic therapy still does not provide favorable outcomes for patients with severe deficits. A brain computer interface (BCI) system can provide the patient with the means for a meaningful therapy session and also address more pronounced deficits. BCI therapy in stroke survivors has been shown to be as effective and safe in arm rehabilitation when compared to intensive robotic assisted repetition therapy but with reduced repetitions needed. Moreover patients with chronic hand weakness that responded poorly to standard rehabilitation efforts have shown a clinically improvement in muscle function from no activity using BCI therapy. Furthermore electroencephalogram (EEG) combined with BCI has led to significantly greater functional connectivity gains when compared to robotic therapy rehabilitation further supporting BCI-induced cortical reorganization. Some of these studies were limited however to simple hand opening and closing and are therefore unlikely to show any gains in higher-level functional ability for example individual finger mobility. Currently robotic therapy for this patient population is lacking in the finger and hand dexterity realm. Nonetheless many critical activities of daily living require a coordinated quick and skillful use of individual fingers. Here we studied the addition of an intracortical BCI system combined with an exoskeleton to allow for more refined individual finger mobility during therapy.

First Author: Carl Beringer (Graduate)	Poster Session: am
Presenting Author: Carl Beringer (Graduate)	Location: 9
Mentor/Lab: Rehab and Neural Engineering Robert A. Gaunt	Category: Brain-Machine Interfaces
Department: Bioengineering	

Title: An optimization-based approach to translate myoelectric signals to muscle activation for Hill-type muscle models

Summary: We have developed a biomimetic model of the hand using a Hill-type framework. Hill-type muscle models require activation as an input but the translation from EMG to activation has not been well-characterized. Using EMG signals from intramuscular electrodes which have many benefits to traditional superficial electrodes we are attempting to use a mathematical optimizer to validate different methods of signal processing to find the EMG-to-activation mapping.

Abstract: Myoelectric prosthetic hands rely on interpreting electromyography (EMG) signals from the residual extrinsic hand muscles to act as prosthetic command signals. Present myoelectric prosthetic hands typically use one of two algorithms for control: pattern recognition in which predetermined prosthetic hand movements or states are commanded based on recognizing previously recorded patterns of activity across multiple signals or direct control in which EMG activity directly controls output for a given degree of freedom (DOF). Both of these approaches face challenges in replicating dexterous movements capable in newer prosthetic hands and are unable to effectively scale beyond 3 DOFs. The Musculoskeletal Biomimetic Model (MBM) is a detailed dynamic model of the hand with Hill-type muscle actuators that use muscle activation as an input signal and that can estimate joint movements by solving a forward dynamic simulation of the hand. Using intramuscular EMG we are able to use up to 16 simultaneous channels of recording. However the feature extraction and signal processing methods required to translate intramuscular EMG recordings to muscle activations have not been well-characterized for this biomimetic approach. In order to identify the EMG-to-activation mapping we used an optimization approach. 14 able-bodied subjects were acutely implanted with intramuscular electrodes in the extrinsic hand muscles . Subjects were asked to perform single and multiple DOF movements of the fingers and wristwhile intramuscular EMG activity and kinematics were recorded. Following experiments the torques of the fingers wrist and thumb joints were calculated using inverse dynamics in MuJoCo simulation software using the position velocity and acceleration of the recorded movements as input. The recorded EMG activity was then converted into activation and then entered into the MBM to calculate output torques and the error between the MBM torques and calculated torques was used as the term to minimize in an optimizer. With this approach we are able to investigate different signal processing parameters (filter type order and frequency) as well as EMG-to-activation methods by comparing the minimized error of each method.

First Author: Christopher Hughes (Graduate)	Poster Session: am
Presenting Author: Christopher Hughes (Graduate)	Location: 10
Mentor/Lab: Robert Gaunt	Category: Brain-Machine Interfaces
Department: Department of Bioengineering	

Title: The complex relationship between frequency and perceived magnitude of intracortical microstimulation in human somatosensory cortex

Summary: We are stimulating a human participant's brain with electrical currents to evoke perceived sensations on the hand. We varied the stimulus parameters (amplitude and frequency) and measured how this affected the perceived intensity of stimulation.

Abstract: It is difficult to grasp and manipulate objects without tactile feedback and yet prosthesis users must work with this limitation. To work towards a solution we implanted microelectrode arrays in primary motor (M1) and primary somatosensory (S1) cortices in a person with a cervical spinal cord injury to enable closed-loop prosthesis control. Using neural activity decoded from M1 our participant can control a dexterous prosthetic limb while sensory feedback is delivered through intracortical microstimulation (ICMS) in S1. Microstimulation on more than 60 of the 64 implanted electrodes reliably evokes sensations in the hand but the perceived intensity of the stimuli evoked can vary significantly from electrode to electrode. We have previously shown that stimulation amplitude has a linear relationship to perceived intensity but the stimulation frequency was always 100 Hz. In non-human primates increasing stimulation frequency decreases detection thresholds but has little effect on discriminability. [1] It has also been suggested that increasing stimulus frequency could increase perceived intensity. Here we explored the effects of stimulus frequency on perceived magnitude in a human participant. To test this we used a free magnitude estimation task where varying stimulus amplitudes (20 50 and 80 uA) and frequencies (20 100 and 300 Hz) were paired and presented in randomized order. For each stimulus pair the participant reported the perceived intensity on a self-selected scale. We found that that perceived intensity increased with stimulation amplitude on all electrodes at all frequencies as expected. However stimulus frequency changed the perceived intensity in idiosyncratic ways that were electrode dependent: when comparing between 20 and 100 Hz on 3 of 8 stimulated channels 20 Hz was associated with increased perceived intensity while on 5 of 8 stimulated channels 100 Hz was associated with increased perceived intensity and these relationships generally held across all stimulus amplitudes. Understanding the relationships between stimulus frequency perceived intensity and other perceptual characteristics could help us improve the perceptual quality of ICMS and develop prostheses that provide a rich sensory repertoire. Ultimately these techniques could also help us understand how inputs are processed more generally in the somatosensory cortex. [1] S. Kim T. Callier G. A. Tabot R. A. Gaunt F. V. Tenore and S. J. Bensmaia “Behavioral assessment of sensitivity to intracortical microstimulation of primate somatosensory cortex.” Proc Natl Acad Sci USA p. 201509265 Oct. 2015.

First Author: Misagh Mansouri Boroujeni (Postdoctoral)	Poster Session: am
Presenting Author: Misagh Mansouri Boroujeni (Postdoctoral)	Location: 11
Mentor/Lab: Robert Gaunt	Category: Brain-Machine Interfaces
Department: Physical Medicine and Rehabilitation	

Title: Differences in Intramuscular EMG Activity in Able-bodied Subjects and Transradial Amputees during Structured Hand Movements

Summary: By combing neural data directly from the residual muscle of an amputee with accurate biomimetic models of an intact hand we can inform the design of bio-inspired controllers that generate prosthesis control signals from the biomechanical function of the muscles and the resulting movement dynamics.

Abstract: Commercial myoelectric prostheses have limited capabilities to simultaneously control multiple degrees of freedom. These prostheses typically rely on signals recorded from surface EMGs placed on the residual limb which are not the full set of extrinsic hand muscles required to actuate individual fingers. In addition standard control approaches usually use pattern recognition or map muscle activity to specific prosthesis movements while largely ignoring underlying biomechanics. Understanding the coordinated activity of extrinsic hand muscles and how their activity results in individual joint movements across a wide range of hand configurations is an essential step towards improving the dexterity of prosthesis control. Here we use dimensionality reduction and clustering techniques to investigate these relationships in able-bodied subjects and an amputee.

First Author: Jeffrey Weiss (Graduate)	Poster Session: am
Presenting Author: Jeffrey Weiss (Graduate)	Location: 12
Mentor/Lab: RNEL/Collinger	Category: Brain-Machine Interfaces
Department: Bioengineering	

Title: Artifact-free recording during human intracortical microstimulation

Summary: We developed a method to record electrical signals produced by the brain while simultaneously applying electrical stimulation to an adjacent brain area. We used this method in a closed-loop brain-computer interface enabling a paralyzed person to both control and feel a robotic arm.

Abstract: We have previously demonstrated brain-computer interface (BCI) control of a robotic arm using signals recorded from motor cortex (M1) and that intracortical microstimulation (ICMS) of human primary somatosensory cortex (S1) can evoke tactile percepts. We wish to combine these results in a closed-loop BCI system which must be capable of continuously recording and stimulating adjacent regions of cortex. This problem is non-trivial due to the presence of large amplitude electrical stimulus artifacts which mask smaller-amplitude extracellular potentials generated by active neurons. Additionally filtering of the recorded signals an essential step for spike detection can compound the problem by distorting artifacts in time such that the signal is corrupted for a duration longer than the stimulus pulse width. We developed a simple artifact elimination (AE) scheme to record in M1 during ICMS of S1 without complex real-time processing. Under an Investigational Device Exemption (NCT01894802) a man with a C5/C6 spinal cord injury was implanted with two recording microelectrode arrays in M1 and two stimulation microelectrode arrays in S1. During each 700 μs biphasic stimulus pulse a sample-and-hold digital filter was applied to the raw recorded signal to eliminate stimulus artifacts prior to additional filtering. A 750 Hz first-order high-pass Butterworth filter was then applied to the signal prior to thresholding for spike detection. These parameters were chosen to meet the specifications of a fast return to baseline after perturbations elimination of filter ringing in the step response and an overall increase in signal-to-noise. This AE scheme allowed for reliable spike detection as soon as 800 □s after the offset of each stimulus pulse corresponding to a 15% loss of neural data when stimulating at 100 Hz. We demonstrated the effectiveness of the AE scheme in a closed-loop BCI task. A 5 DOF velocity decoder was trained to control a robotic arm. The subject was instructed to use the robotic arm to transfer an object across a 20 cm region as many times as possible during a two-minute period. During ICMS trials 8 electrodes were simultaneously stimulated between 18-46 μA at 100 Hz when the fingers generated torque against the object. A one-way ANOVA found significant differences in performance between baseline (no ICMS) ICMS and ICMS+AE conditions ($p < .01$). Post-hoc tests revealed a significant decrease in performance with ICMS without AE compared to baseline ($p < .01$) but no significant difference between baseline and ICMS+AE conditions ($p = .621$). The proposed system is relatively simple to implement and requires minimal parameter tuning to produce reliable recordings during ICMS for closed-loop BCI control.

First Author: Jordan Williams (Postdoctoral)	Poster Session: am
Presenting Author: Jordan Williams (Postdoctoral)	Location: 13
Mentor/Lab: Andrew Schwartz Motorlab	Category: Brain-Machine Interfaces
Department: Systems Neuroscience Institute	

Title: Peripheral optogenetic stimulation of motor function in non-human primates toward restoration of volitional motor control in a brain-machine interface

Summary: This work examines the use of viral gene therapy techniques in monkeys in order to stimulate muscle activity using light as an alternative to traditional electrical stimulation. The results presented here present a first step toward translating this technology to restore voluntary movements and independence to patients such as those with spinal cord injury

Abstract: Artificial muscle activation can be used to reanimate muscles that have been rendered inactive by disease or injury. Most approaches to muscle reanimation have used functional electrical stimulation (FES) which has several considerable drawbacks. Recently peripheral motor nerves expressing channelrhodopsin (ChR2) have been optically stimulated to elicit functional muscle activity in transgenic mouse lines as well as through viral mediation in rodents. Functional optical stimulation (FOS) of muscle activity in this manner offers several advantages over FES in terms of its potential use in chronic BMI applications. Prior to realizing its potential as a human gene therapy however viral transduction of light-sensitive opsins such as ChR2 in peripheral motor nerves must be demonstrated and optimized in non-human primates – a task which has proven difficult for viral optogenetic techniques in the brain and has yet to be demonstrated in the periphery. Here we present successful transduction of ChR2 and a newer variant Chronos in peripheral motor nerves of adult macaques following injection of AAV6 based vectors into target muscles. EMG activity elicited acutely through fiber optic stimulation demonstrated selective recruitment of muscle fascicles within a targeted muscle. In addition we examined patterns of sensitivity to optical stimulation histology multi-photon and whole sample optical imaging techniques to evaluate the expression patterns of opsins in the spinal cord and periphery with implications for chronic LED cuff placement. Together these results can help direct avenues of investigation that need to be addressed before this therapy may be translated to clinical use.

First Author: Angelica Herrera (Graduate)	Poster Session: am
Presenting Author: Angelica Herrera (Graduate)	Location: 14
Mentor/Lab: Jennifer Collinger	Category: Brain-Machine Interfaces
Department: Bioengineering	

Title: Grasp force encoding in human primary motor cortex during attempted isometric grasping

Summary: Using a force match task grasp force can be accurately classified from neural recordings in human primary motor cortex.

Abstract: Brain-computer interfaces (BCIs) can restore limb function by controlling a prosthetic arm with signals recorded from primary motor cortex (M1) and recently have begun to incorporate sensory feedback through stimulation of somatosensory cortex (S1). With the ability to sense graded levels of tactile feedback we aim to extend the capabilities of BCIs to control grasp force. Here we examined whether motor cortex encoded a force signal during an attempted isometric grasp in a virtual reality environment (MuJoCo). A 28-year old male with tetraplegia was implanted with two 88-channel and two 32-channel intracortical microelectrode arrays in M1 and S1 respectively. We recorded neural data while the participant used a virtual hand to grasp spherical objects at three force levels indicated by a spoken audio cue (gentle medium and firm ranging from 4 to 12 N). He attempted to perform the task while the computer controlled the kinematics and grasp force. Graded stimulation was provided as the object was compressed based on the measured reaction force on the index finger in MuJoCo. The participant had five seconds to close the hand around the object and was required to maintain hold of it for two seconds at the specified force level. To determine whether M1 activity encoded force-related information we trained a Naïve Bayes classifier to obtain the classification accuracy of the force levels using five sets of 27 trials collected over three test sessions. A time series of accuracies was computed by averaging each channel's firing rate over a 1 second sliding window (200 ms step) for the duration of the hold phase (2 seconds). The model was validated using leave-one-out-cross validation. Classification accuracy was high at 70 +/- 5% throughout the isometric grasp phase for all six time bins tested with no significant differences in classification accuracy between the bins. In addition to the 70% of correctly classified force targets 16 +/- 13% of incorrectly classified trials were to the adjacent force level when classifying data during the first second of the isometric grasp. Our results demonstrate that grasp force can be well classified from neural recordings in M1. In the future we plan to analyze the effects of providing feedback on classification accuracy. Currently we use a linear mapping of stimulation amplitude to force levels; however this is not naturalistic. Future work will involve developing more effective ways of incorporating stimulation such as using biomimetic stimulation patterns. We will also investigate the most effective ways of implementing force decoding with BCI control to provide accurate manipulation of objects of different sizes and compressibility.

First Author: Yashar Aucie (Graduate)	Poster Session: am
Presenting Author: Yashar Aucie (Graduate)	Location: 15
Mentor/Lab: PittMotion Lab / Gelsy Torres-Oviedo	Category: Brain-Machine Interfaces
Department: Bioengineering	

Title: Innovative shoes induces locomotor learning correcting step asymmetry

Summary: we have developed a pair of portable shoes that enables the adaptation of step length asymmetries during over ground walking. This can help us improve the gait of post-stroke patients more efficiently.

Abstract: There is a clinical interest to correct step length asymmetry post-stroke (i.e. limp) because it impairs patients' mobility. Promising studies have shown that stroke survivors recover gait symmetry after walking on a split-belt treadmill that augments their step asymmetry by moving the legs at different speeds. However the transfer of gait improvements to over ground walking is limited. We hypothesize that gait improvements would be more general if we could induce locomotor learning by augmenting step asymmetry like split- belt treadmills while walking over ground. Thus we developed a portable device called Nimbus which are motorized shoes that can move the legs at different speeds while walking over ground. In this study we determined if the Nimbus shoes could induce similar gait adaptation effects to those observed on the split-belt treadmill. Thus we compared walking kinematics between subjects wearing the Nimbus shoes on a regular treadmill (n=7) vs. walking on a split-belt treadmill (n=7). Both groups experienced an adaptation period when the legs move at different speeds. Positions from the ankle and the hip were collected bilaterally and used to compute step length step position and step time asymmetry which are known to adapt during split-belt walking. These parameters were used to contrast between groups 1) the extent of adaptation (i.e. changes in gait from early to late adaptation) and 2) the magnitude of after-effects (i.e. changes in gait before and after the adaptation period). Overall the Nimbus group exhibited locomotor adaptation and after-effects like the split-belt group. Both groups had same extent of adaptation ($p>0.153$ for all parameters) and same after-effects ($p>0.071$for all parameters). In sum our results indicate that the Nimbus shoes are portable devices that can induce error-based locomotor learning as split-belt walking which is holds the great promise of inducing locomotor learning in patients that will improve their gait during real-life situations beyond the clinic.

First Author: Emily Oby (Postdoctoral)	Poster Session: am
Presenting Author: Emily Oby (Postdoctoral)	Location: 16
Mentor/Lab: Aaron Batista	Category: Brain-Machine Interfaces
Department: SNI	

Title: Learning to generate new patterns of neural population activity

Summary: If we can understand the neural mechanisms of learning then we can harness those mechanisms to improve clinical applications of brain machine interfaces. In the lab we train animals to learn very challenging BMIs and can observe the neural strategies whereby they learn.

Abstract: Learning requires networks of neurons to generate new patterns of activity. We can study the changes in neural population activity that accompany learning by using a brain-computer interface (BCI) in which users modulate neural activity to control a computer cursor. A BCI paradigm has advantages for studying the neural population mechanisms of learning because in a BCI we record from all the neurons that directly influence the behavior the causal relationship between neural activity and behavior is known exactly and that relationship can be altered by the experimenter to induce learning. Here we examine the changes in population activity in primary motor cortex (M1) of Rhesus monkeys that accompany the learning of a new BCI mapping for which optimal performance would require the generation of new population patterns of activity. We use dimensionality-reduction techniques to observe neural changes. The activity of a neural population can be represented as a point in a high-dimensional neural space wherein each dimension corresponds to the activity of one neuron. Characteristic patterns of co-modulation among the neurons comprise a low dimensional subspace within the neural space. We refer to this subspace of naturally-occurring neural activity patterns as the intrinsic manifold. We confront animals with new BCI mappings for which successful control would require neural activity patterns that are outside the intrinsic manifold. We find that when given many days of practice animals can learn to use these new BCI mappings. This raises the question of how neural activity patterns develop to support this new behavioral capacity. Here we present three neural strategies for learning. A suboptimal strategy is to take advantage of the existing population activity patterns by reassociating them with different movements. While this strategy could lead to behavioral improvements control is not expected to be optimally efficient. Optimal strategies require activity patterns to realign with the BCI mapping in a manner that maximizes behavioral performance. This realignment could happen in a way that adheres to the existing co-modulation relationships i.e. the population activity patterns are within the intrinsic manifold. Alternatively realignment could disregard the existing co-modulation relationships i.e. the population activity patterns are outside of the intrinsic manifold. This outside manifold realignment would yield the best control but is also the strategy we expect to be hardest for a network of neurons to achieve. We see evidence of a combination of these strategies within a given experiment. We conclude that under sufficient learning pressure animals can indeed exhibit new neural population activity patterns. However this learning takes time and even then it seems to occur only when necessary.

First Author: Alan Degenhart (Postdoctoral)	Poster Session: am
Presenting Author: Alan Degenhart (Postdoctoral)	Location: 17
Mentor/Lab: Aaron Batista	Category: Brain-Machine Interfaces
Department: Systems Neuroscience Institute	

Title: A self-recalibrating brain-computer interface

Summary: Brain-computer interfaces (BCIs) can provide restoration of function for individuals with paralysis but are sensitive to instabilities in the neural activity used for control. We developed a self-recalibrating BCI system that leverages characteristics in neural population recordings to maintain performance in the presence of these instabilities. This work has the potential to increase the quality of life for individuals with paralysis by eliminating the burden of frequent BCI calibration.

Abstract: A key problem limiting the clinical translation of intracortical brain-computer interface (BCI) technology is that of stability. Over time neural signals recorded by penetrating microelectrode arrays can change due to a number of factors including glial scarring electrode micro-motion and mechanical failure. To combat these changes BCI systems typically rely on explicit daily recalibration of their decoding algorithms to recover satisfactory control. Recalibration procedures require the user's participation and may be burdensome in a clinical setting. To overcome this shortcoming we present an algorithm for decoding a continuous control signal which performs automatic recalibration by leveraging the low dimensional structure found in neural population activity. We make the assumption that the day to day relationship between a low-dimensional representation of neural activity and intended BCI movements is constant even if the set of neurons recorded and the characteristics of the signals vary from day to day. By finding the alignment between low-dimensional spaces of the population activity estimated at different points in time decoding parameters can be automatically updated based only on observation of new neural activity and without knowledge of intended movement kinematics. This allows recalibration to occur in the background and requires no time or effort on the part of the user. We assessed performance of the self-recalibrating algorithm in a series of closed-loop BCI experiments with two Rhesus macaques implanted with Blackrock arrays in primary motor cortex (M1). Experiments began with the calibration of a well-controlled "baseline" decoder. As the neural activity within a single experimental session is often stable we generated recording instabilities by perturbing the neural activity using: (1) baseline shifts where a random constant offset was added to the firing rate of each neuron (2) silencing where the firing rates of a subset of neurons was set to zero (3) swaps where the activity of a subset of neurons was replaced with that of held-out neurons or (4) combinations of baseline shifts silencing and swaps which might mimic clinically severe recording instabilities. In 41 of 42 single-day experiments we find that the self-recalibrated decoder was able to significantly improve performance in the presence of the perturbation. Furthermore we find that the self-recalibrating decoder is able to sustain BCI performance over multiple days in the presence of both natural and artificial instabilities. This work has the potential to increase the viability of BCI systems for clinical use.

First Author: Witold Lipski (Faculty)	Poster Session: am
Presenting Author: Witold Lipski (Faculty)	Location: 18
Mentor/Lab: Richardson	Category: Brain-Machine Interfaces
Department: Department of Neurosurgery	

Title: Speech encoding in the human subthalamic nucleus

Summary: The neurophysiological mechanisms underlaying speech production is understood largely in terms of neocortical structures located on the brain surface because they can be studied non-invasively in humans. However the contributions of deep brain structures such as the subthalamic nucleus are not well understood. Here we present evidence of speech encoding in the subthalamic nucleus and suggest ways in which these data can influence our models of speech production as well as how these findings can improve treatment of patients with movement disorders.

Abstract: Speech production and control is disrupted in many neurological diseases that involve the basal ganglia. Notably hypophonia and hypokinetic dysarthria (characterized by decreased motor gain) are prevalent in patients with Parkinson's disease (PD). Deep brain stimulation (DBS) of the subthalamic nucleus (STN) produces predictable improvements in other motor symptoms of PD but does not result in consistent improvement in speech and can negatively impact language function. However neurophysiological models of speech production typically do not account for the involvement of basal ganglia nuclei. To examine the role of the STN in speech production we recorded STN neuron activity STN local field potentials (LFP) and spoken acoustics while 14 PD subjects performed a speech task during awake microelectrode recording (MER)-guided DBS surgery. On each trial subjects were asked to read aloud a consonant-vowel-consonant syllable presented on a computer screen. Spike waveforms were sorted into single- and multi-unit recordings. LFP signals were bandpass filtered into canonical bands (delta 2-4Hz theta 4-8Hz alpha 8-12 Hz beta 13-30Hz and gamma 50-90Hz). Power changes were calculated as a z-score relative to baseline after applying a Hilbert transform to estimate signal amplitude and phase. First we found evidence for the participation of STN neurons in speech production. Nearly half of single unit recordings (22 of 45 in 13 subjects) showed either increases or decreases in firing rate when aligned to speech onset. STN LFP recordings also showed evidence for modulation related to speech production. Consistent with tracking the motor aspects of speech we found an increase in gamma power in 13/14 subjects locked to the onset of speech but not locked to cue presentation. In contrast theta power increases were locked to cue presentation rather than speech onset (11/14 subjects) and this modulation was associated with an increase in inter-trial phase consistency (ITPC) (7/14 subjects) suggesting a role for theta-encoding in cognitive processing prior to speech onset. Likewise we observed alpha and beta power decreases locked to cue presentation but not to speech onset. Importantly in a subset of these recordings we observed differences in both alpha and beta ITPC that were specific to whether the presented stimulus was a real word or a non-word. Lastly we observed delta power and ITPC increases in relation to both cue presentation and speech onset (11/14 subjects) further suggesting that several types of speech-related information transfer occur within the STN.

First Author: Kristin Quick (Postdoctoral)	Poster Session: am
Presenting Author: Kristin Quick (Postdoctoral)	Location: 19
Mentor/Lab: Jen Collinger and Rob Gaunt	Category: Brain-Machine Interfaces
Department: Physical Medicine and Rehabilitation	

Title: Velocity-Tuning of Sensory Cortex during Cursor and Hand Shaping Tasks

Summary: A participant with chronic spinal cord injury was able to use sensory cortex instead of motor cortex to control a brain computer interface.

Abstract: Introduction: Neurons in motor cortex (M1) are known to relate their activity levels to movement kinematics such as velocity. This velocity-relationship can be used by a person with paralysis to control an external device such as a computer cursor or the grasping of a robotic hand. When the person attempts to control the device the brain computer interface (BCI) translates their M1 activity into a velocity command which moves the device to the desired position. In addition to M1 studies have also found that sensory cortex (S1) increases its neural activity during movements (di Prampero et al. 1996) and that neurons are tuned to the direction of movement (Prud'homme and Kalaska 1994). However it is unknown whether S1 is also tuned to the velocity of movement. If tuned to movement velocity it might be possible to instead use S1 activity to control an external device. In this set of experiments a participant performed two types of tasks. In the first task a cursor moved on a computer screen. In the second task a robotic hand moved between different hand shapes. We hypothesized that 1) S1 would show velocity-tuning during these tasks. Additionally since the S1 arrays were placed in the hand area we expect that 2) S1 velocity-tuning would be stronger for the hand shaping than cursor movements and 3) the performance of the S1 decoder for hand shaping would be higher than the performance of the S1 decoder for cursor movements. Methods: A participant with chronic C5 motor and C6 sensory AIS B spinal cord injury was implanted with two 88-channel intracortical microelectrode arrays in M1 targeting the arm and hand representation and two 32-channel microelectrode arrays targeting the hand region of area 1 in S1. To provide a fair comparison 64 M1 channels with the same spatial layout as the S1 channels were used in this work. We recorded neural activity while the subject attempted to mimic 2D cursor or hand shaping movements that were under computer control. A linear velocity-based encoding model was fit to the neural activity recorded on each channel. We then compared the S1 and M1 model fits for the cursor task and the hand shape task. After comparing model fits we created S1-only and M1-only decoders (optimal linear estimator OLE) for both the cursor and hand shape tasks (total of 4 decoders). To allow for a more complete comparison online BCI performance was tested with computer assistance that cancelled any decoded velocities orthogonal to the path from the current position to the target. Results: We found significant velocity-tuning in S1 to both cursor movements and hand shape movements. However S1 velocity-tuning was significantly reduced compared to M1 for both the cursor and hand shape tasks. When looking in more detail at S1 we found that velocity-tuning for hand shaping was significantly stronger than for cursor movements. Next the four decoders were tested. For cursor movements the S1 decoder achieved 47% success and the M1 decoder achieved 100% success. For hand shaping the S1 decoder achieved 60% success and the M1 decoder achieved 90% success. We found that the participant could utilize the S1 decoder for hand shaping (S1 performance was 67% of M1 performance) better than the S1 decoder for cursor movements (S1 performance was 47% of M1 performance). Conclusion: As expected velocity-tuning was present in S1 for both cursor movements and hand shaping movements albeit at a reduced strength compared to M1 tuning. Additionally the strength of S1 velocity-tuning was stronger for hand shaping than cursor movements. This finding carried over into the participant's performance during online control. The S1 hand shape decoder outperformed the S1 cursor decoder perhaps because the S1 hand shape decoder was more congruent with the cortical hand representation in which the arrays were placed. Velocity-tuning has been shown to

model M1 activity well. However it is possible that S1 activity may better fit tuning models that encode a different movement parameter(s) or incorporate a lag between the kinematics and neural activity. An optimized S1 encoding model would likely further improve S1 BCI control.

First Author: Nathaniel Sisterson (Graduate)	Poster Session: am
Presenting Author: Nathaniel Sisterson (Graduate)	Location: 20
Mentor/Lab: Brain Modulation Lab/Mark Richardson MD PhD	Category: Brain-Machine Interfaces
Department: Department of Neurological Surgery	

Title: Theta-gamma wave ratio differentiates spiking and low voltage seizure onset

Summary: The NeuroPace Responsive Neurostimulator is an implantable device recently approved for people with severe epilepsy that reduces the number of seizures using electrodes and programmable detectors to identify abnormal brain activity and deliver stimulation therapy. We analyzed brainwave activity recorded from the implantable electrodes in one patient and demonstrated that the ratio of theta to gamma brain waves was different during the 20 seconds preceding two common seizure-onset patterns. This difference in theta to gamma ratios may further improve seizure outcomes by allowing detection and stimulation settings specific to the type of seizure.

Abstract: Hypothesis Closed-loop or responsive neural stimulation systems represent a new and promising therapy for managing the debilitating and degenerative seizures in the 75% of drug-resistant epilepsy patients who are either not surgical candidates or do not respond adequately to surgery. However the mean time to 50% seizure reduction of 2 years is too long delaying quality of life benefits while incurring serious healthcare costs. The identification of biomarkers in intracranial electroencephalography (iEEG) recordings may better differentiate seizure types and accelerate optimal detection and stimulation settings. We hypothesize that electrographic seizures characterized by spiking versus low voltage fast seizure onset patterns have a 3:2 or greater ratio of pre-seizure electrographic theta-gamma power ratios. Methods iEEG recordings were captured by the closed-loop NeuroPace RNS device for one patient with mesial temporal lobe epilepsy. The recordings were manually reviewed by an expert to differentiate electrographic seizures from inter-seizure bursts and to categorize seizures as either low-voltage fast or spiking onset. Recordings with <20s of pre-seizure data available were removed from the set. Spectral analysis of the 20s preceding seizure onset was performed for the theta (4-7 Hz) and gamma (30-70 Hz) bands for each channel of each recording using Fast Fourier Transform. An unpaired T-test was used to compare mean theta-gamma power ratios for low-voltage fast versus spiking seizure types. Results A total of 1532 four-channel iEEG recordings representing a 26 month period were screened resulting in 113 (47 spiking and 66 low-voltage fast) 20s pre-seizure iEEG segments with four channels each (452 total segments). The mean theta-gamma ratio for spiking onset seizures was 0.200 (median=0.119) and 0.137 (median=0.114) for low-voltage fast onset seizures. The ratio of theta-gamma ratios was 2.9:2 (0.063 absolute difference; SD=0.324; p<0.05) for seizures characterized by spiking versus low-voltage fast onset. Conclusions Theta-gamma power ratio in the 20s preceding seizure onset is greater in spiking versus low voltage fast onset in one patient with mesial temporal lobe epilepsy which may be a useful biomarker for spiking versus low-voltage fast seizures.

First Author: Xin 'Sally' Zheng (Graduate)	Poster Session: am
Presenting Author: Xin 'Sally' Zheng (Graduate)	Location: 21
Mentor/Lab: Tracy Cui	Category: Brain-Machine Interfaces
Department: Bioengineering	

Title: Soft and elastomeric electrodes for muscle and nerve interfaces

Summary: We have developed an implantable electrode that is soft and elastic. These electrodes are capable of interfacing with both the nerves and the muscle. Chronically these electrodes elicit minimal foreign body response.

Abstract: Functional electrical stimulation of the peripheral nervous system (PNS) has the potential to restore functions of amputees and to treat neuromuscular atrophy. Electrodes that are chronically implanted in the PNS use conventional conductive materials such as stainless steel (e.g.Cooner wire) and platinum wires which are significantly stiffer than neural tissue and cause inflammatory tissue response and performance failure. Many efforts have been made to develop flexible electrodes for PNS interfaces such as the polyimide based thin film longitudinal intrafacicular electrode (Navarro et al 2007) and the polydimethylsiloxane based flat interface cuff electrode (Tyler et al 2002). We have developed a soft and elastomeric electrode capable of electrophysiological recording and stimulation for the brain (Kolarcik et al 2015; Du et al 2017). The soft electrode consists of a blend of a PEG-modified PEDOT conducting polymer and polydimethylsiloxane elastomer and utilizes an electrically-insulating fluorosilicone coating. This composition had a Young's modulus of 974kPa and showed excellent chronic tissue integration with healthy neurons at the interface and reduced BBB leakage and gliosis. To translate this technology to the more dynamic and mechanically demanding peripheral environment carbon nanotubes have been incorporated into the conducting elastomer core to enhance electrical properties of the composition while maintaining favorable mechanical properties. In acute in vivo evaluations electrical stimulation is achieved through implanting a stimulating soft wire electrode (90 um) in the rat's sciatic nerve and two recording soft wire electrodes (180 um) in the rat's gastrocnemius muscle. The 90 um soft wires successfully elicited muscle twitch at 2 uA (biphasic pulse 500 uS pulse width 50uS interphase delay) and resulted in a graded increase in compound muscle action potential of the rat gastrocnemius measured by the 180 um soft wires. For recording a 90 um soft wire was implanted in the tibial nerve and manual brushing of the posterior hind limb elicited multiunit activity and sortable single units. Chronically the soft wires implanted in the muscle remained intact and demonstrated efficacy in eliciting muscle twitch one month after implantation. Post mortem histology showed decreased fibrotic scarring around the soft wire implant compared to the stiff wire control implants. Our soft wires have the potential to improve the interface with the peripheral nervous system and to improve the control of prosthetic limbs for research and clinical applications.

First Author: Patrick Beukema (Graduate)	Poster Session: am
Presenting Author: Patrick Beukema (Graduate)	Location: 22
Mentor/Lab: CoAx lab / Tim Verstynen	Category: Motor
Department: Neuroscience	
Title: Decoding single finger movements versus movement sequences	
Summary: A large part of the brain is dedicated to motor control. We show what specific parts of the brain are involved in generating single finger movements like tapping versus sequential movements like playing piano.	
Abstract: Coordinated finger movements are ubiquitous in daily life. Using representational similarity analysis of BOLD data from human subjects we isolate the motor control network for individual finger movements and sets of movements during the production of cued sequences. In a second set of experiments we show that a movement sequence network and a goal sequence network involve largely distinct regions in somatomotor cortex and visual cortex respectively but partially overlap in premotor dorsal cortex.	

First Author: Nicholas Card (Graduate)	Poster Session: am
Presenting Author: Nicholas Card (Graduate)	Location: 23
Mentor/Lab: Omar El-Gharbawie	Category: Motor
Department: Bioengineering	

Title: Intrinsic connections of motor cortex columns revealed with intracortical microstimulation and optical imaging in squirrel monkeys

Summary: To determine how primary motor cortex (M1) coordinates the activity of many hand and arm muscles at once we used an optical imaging technique to visualize local connections within the forelimb representation of squirrel monkey M1. We found that zones in M1 are preferentially connected to other M1 zones with similar muscle targets.

Abstract: In primary motor cortex (M1) a roughly concentric topography exists for the motor representations of the hand elbow and shoulder. Cortical columns within these representations send corticospinal projections that can influence activity in groups of arm and hand muscles. The muscle synergies needed for manual movements are therefore predicated on coordinated activity between M1 columns within the arm and hand representations. Multiple communication channels have the potential to coordinate activity in M1 columns. Intrinsic M1 connections represent the most direct channel of communication between M1 columns but are perhaps the least understood among M1 connections. The objective of the present study is to investigate the spatial organization of the intrinsic connections of M1 in columns within the arm and hand representations. In three squirrel monkeys we focused on mediolateral rows of cortical columns in M1 wherein motor output changes but other defining features are invariant. To study an individual column we first determined the output targets of that column via intracortical microstimulation (ICMS) and electromyographic (EMG) recordings. Second we identified zones in M1 that are connected to that column using ICMS (trains of 150 pulses 0.2 ms/pulse 300 Hz 1000 μm below pia) and concurrent intrinsic signal optical imaging (630 nm illumination). For all M1 columns investigated in this study the most prominent activation was a spatial cluster (~ 2.0 mm2) of contiguous columns that surrounded the stimulating microelectrode. In addition columns were preferentially connected with other clusters (~ 0.5 mm2) of columns. The muscle targets of the connected columns overlapped with the muscle targets of the microstimulation site. Our results build on tracer studies that showed that the anatomical connections of the thumb representation in monkeys (Huntly and Jones 1991) and the wrist representation in cats (Keller 1993) are widely distributed across the entire forelimb representation. Here we show that the functional connections of M1 columns within the forelimb representation are spatially biased towards M1 columns that target the same muscle groups. Thus our results to date suggest that functional connections within M1 may be primarily concerned with coordinating matched columns. In this framework other communication channels (e.g. thalamic inputs intra-areal connections) may be responsible for coordinating nonmatched M1 columns. We are currently testing the effects of ICMS in one column on the activity of single units in connected columns to determine if interactions between connected columns are excitatory or inhibitory.

First Author: Scott Kennedy (Graduate)	Poster Session: am
Presenting Author: Scott Kennedy (Graduate)	Location: 24
Mentor/Lab: Schwartz	Category: Motor
Department: Bioengineering	

Title: Motor cortical encoding of arm impedance during the coordinated control of both force and movement

Summary: When we interact with an object to move it from one place to another we have to coordinate the movement of the object with the force that we exert on the object. If the relation between movement and force is not known then we can stiffen the arm to still achieve the desired movement. Here we present motor cortical signals that correlate with both force and movement; these correlates could explain the strategy of stiffening the arm to interact with objects.

Abstract: The coordinated control of both force and movement is fundamental to object interaction. However in many cases the relation between force and movement is inherently unstable or unpredictable and thus can never be learned. A framework that is robust to this inherent uncertainty is impedance control. In this study we tested a neurophysiological hypothesis derived from the framework of impedance control. We trained a monkey to pull on a handle that was locked in place until a specific force threshold was crossed. Then the handle was suddenly released to move along a track. The monkey was required to stop the handle in one of four different targets spaced along the track. We observed how the firing rates of motor cortical neurons varied with target position. For comparison we repeated this procedure across four different force thresholds. We observed that arm impedance increased as the force threshold increased. We also observed that arm impedance increased as the target moved closer to the handle's lock position. This pattern was consistent with the framework of impedance control and led to our specific hypothesis: if a neuron encodes information about impedance then that information should be consistent across thresholds and across targets. Indeed we found that 20 of 101 neurons had firing rates that were correlated with both target and threshold. In addition 18 of those neurons had correlations that were consistent with impedance encoding. Specifically the firing rates of 8 neurons were negatively correlated with target and positively correlated with threshold i.e. positively correlated with impedance. The remaining 10 neurons had the opposite correlation. These results demonstrate that the simultaneous encoding of both force and movement in the firing rates of motor cortical neurons can explain the variation of arm impedance during object manipulation. This suggests the possibility that impedance control could be implemented by the motor system and could provide a unifying framework that describes the coordinated control of both force and movement.

First Author: Steven Suway (Graduate)	Poster Session: am
Presenting Author: Steven Suway (Graduate)	Location: 25
Mentor/Lab: Andy Schwartz	Category: Motor
Department: Neurobiology	

Title: Temporally segmented coordinate systems in the motor cortex

Summary: We previously found evidence that the motor cortex changes functional state rapidly during behavior. However the behavioral factors driving these state changes are not clear. Here we provide preliminary evidence that visual information can be an important driver of these state changes which is surprising given that the motor cortex is often assumed to participate in lower-level muscle activation.

Abstract: We recently showed that directional tuning in motor cortical (M1) neurons is temporally segmented during center-out reaching (Suway et al. 2017). We found that preferred directions (PDs) change over time in discrete steps between segments but are stable for the duration of each segment. This raised the possibility that M1 changes functional state rapidly during behavior. Our lab has previously shown that some neurons in M1 express directional tuning in vision-centered coordinates rather than arm-centered coordinates. Here we explored the relationship between step-changes in PD and the coordinate systems of those PDs. We used a visuomotor perturbation to dissociate vision from action during reaching. Preliminary data show that the tuning of single neurons can change between segments to/from “arm coordinates” or “vision-sensitive” coordinates. This result extends our recent finding that directional tuning of single neurons occurs in discrete segments and lends support to the notion of discrete changes in functional state in M1 during behavior.

First Author: Alessandro Salatiello (Graduate)	Poster Session: am
Presenting Author: Alessandro Salatiello (Graduate)	Location: 26
Mentor/Lab: Dr. Gelsy Torres-Oviedo	Category: Motor
Department: Bioengineering	

Title: Interference in Locomotor Adaptation

Summary: In this work we aimed to study the interaction of the instantiation of competing memories of adapted walking patterns. We found that this competition manifests itself as a reduction in the rate of memory expression.

Abstract: Split-belt treadmill walking in which legs move at different speeds can be used to improve patients' mobility by correcting their gait asymmetry (e.g. Reisman et al 2013). For this strategy to be effective it is necessary to maximize the retention of motor memories acquired during the training. In order to do so it is important to know how motor memories learned within the same environment influence each other. In this study we specifically tested whether learning two locomotor patterns counteracting equal and opposite perturbations is possible or instead the memories interfere with one another. To this end we studied unimpaired subjects' ability to counteract the same perturbation twice after either experiencing an opposite perturbation in-between (interference group n=8) or walking without any perturbation (savings group n=8). Critically unlike prior work (Malone et al 2011) we removed the opposing perturbation gradually to reduce the experienced errors known to reinforce the motor memory initially learned (Herzfeld et al. 2014). As a measure of error we used step length asymmetry. We compared across groups 1) the change in initial error that subjects experienced when the perturbation was introduced 2) the change in steady state value reached and 3) the percent change in adaptation rate. We found that while both groups had similar initial change in errors (and thus where similarly perturbed p=0.69) and similar change in steady state values (indicating a comparable ability in facing the perturbation at steady state p=0.11) the dynamics of adaptation were significantly different. In fact the interference group readapted 38.27% slower (p=0.035 95% bootstrap CI [3.52% 80.99%]) whereas the savings group readapted as fast as during the first exposure. In sum our results indicate that the memory of adapted walking patterns is subject to interference and that this memory can be reinforced by the errors experienced during de-adaptation. These findings can inform the design of more effective rehabilitation techniques to counteract step length asymmetry in stroke survivors.

First Author: Pablo Iturralde (Graduate)	Poster Session: am
Presenting Author: Pablo Iturralde (Graduate)	Location: 27
Mentor/Lab: Gelsy Torres-Oviedo	Category: Motor
Department: Bioengineering	

Title: Adaptation of muscle-activity during split-belt walking predicts the extent of human locomotor learning

Summary: We studied the evolution of muscle activity during a task that required subjects to adapt the way they walk on a treadmill. We found that fast changes in walking conditions lead to feedback responses that are adapted as subjects spend more time walking in the altered environment. Further we were able to predict how subjects would react to going back to normal walking afterwards.

Abstract: Split-belt treadmill walking has been used to study the locomotor control and adaptation in humans and has been suggested as a therapeutic tool to restore gait symmetry in chronic stroke patients. While muscle activity offers direct insight into the nervous system's regulation of locomotion and learning mechanisms little is known about how muscle activity changes during a split-belt protocol. Here we present a thorough characterization of muscle activity in 15 lower limb muscles on each leg during a split-belt treadmill adaptation and de-adaptation protocol. Analysis is focused on the relation between activity during the adaptation condition and the aftereffects during the deadaptation condition. As expected muscle activity was consistent with feedback postural responses when the split-belt condition was introduced. In other words subjects where perturbed by the split-belt environment leading to reactive responses intended to maintain stability. These feedback responses are extinguished and an asymmetric muscle activation pattern emerges as subjects adapt to the split-belt condition. We observed that the adapted muscle activation patterns are inconsistent with strictly ipsilateral speed-dependent modulation which highlights the bilateral nature of walking. Interestingly we found feedback responses are modulated by the duration of the split-belt condition suggesting that they reflect changes in subjects' expectation of the environment. The extent of this adaptation was age dependent with older subjects showing less adaptation. Surprisingly aftereffects in muscle activity were dominated by feedback control responses rather than feedforward (learned) activity.Finally we fitted a linear time-invariant space-state model to characterize the temporal evolution of muscle activity during adaptation and de-adaptation. Notably our model was able to predict the aftereffects when fitted strictly to data observed during the split-belt condition providing a first description of the relation between behavior during adaptation and its consequences for normal walking (learning). Taken together our results suggest that feedback control rather than feedforward is the main driver of observed aftereffects in this task setting it apart from other modalities of motor learning such as reaching in a force field. These results need to be considered when designing split-belt treadmill protocols for therapeutic purposes.

First Author: Seungmoon Song (Postdoctoral)	Poster Session: am
Presenting Author: Seungmoon Song (Postdoctoral)	Location: 28
Mentor/Lab: Motor Adaptation and Rehabilitation Group / Gelsy Torres-Oviedo	Category: Motor
Department: Department of Bioengineering	

Title: Can split-belt treadmill walking be explained with a reflex-based model?

Summary: Human gait adaptation for example on split-belt treadmills is often explained by the modulation of central pattern generators which is assumed to govern the spinal locomotor circuits. Here we show with a neuromechanical simulation model that such a human gait adaptation on split-belt treadmills can be explained without central pattern generators but by modulations of spinal reflexes. Moreover with this spinal-reflex based model we investigate the physiological criteria that drive gait adaptation such as metabolic energy and muscle fatigue.

Abstract: Gait adaptation on split-belt treadmills provides insights on the underlying control structure for walking. For example observations on infants and adults walking on split-belt treadmills with various speed configurations have led to a consensus that the locomotion controller consists of separate functional networks for each leg and for different locomotion modes (e.g. forward vs. backward walking). However most of the interpretations of these experiments are based on an assumption that the spinal motor circuits are governed by central pattern generators (CPGs). Here we investigate the possibility that humans adapt their gait without CPGs. In other words we evaluated the extent to which human gait adaptation on split-belt treadmills moving the legs at different speeds can be reproduced in simulation by a spinal-reflex-based neuromechanical model which consists of a network of spinal reflexes mediated by supraspinal control without CPGs. Our results show that the reflex-based neuromechanical model can successfully generate stable split-belt walking with one leg moving at 1.5 m/s and the other one at 0.5 m/s. Moreover our preliminary results show that when the reflex control parameters are optimized for minimum metabolic consumption the model reproduces most of the stepping features observed in human split-belt treadmill walking. Specifically we performed a one-sample t-test to find significant differences between the gait features of nine healthy subjects and those produced by our model and found that both the subjects and the model converged to the same step-position ($p=0.25$) step-time ($p=0.010$) and step-velocity ($p=0.056$). Interestingly we found differences in the step length asymmetry reached by the simulation and the experimental results ($p<0.001$) suggesting that metabolic consumption may not be the only factor optimized in humans. We are currently investigating the effect of optimizing for different costs including metabolic energy muscle fatigue and gait asymmetry to explore the physiological basis of human gait adaptations upon sustained changes in the walking environment imposed by the split-belt treadmill. Once we identify the cost function driving locomotor learning we will further investigate the contributions of individual reflex pathways in the gait adaptation of the model. The findings will allow us to augment gait rehabilitation with devices such as the split-belt treadmill.

First Author: Uday Jagadisan (Postdoctoral)	Poster Session: am
Presenting Author: Uday Jagadisan (Postdoctoral)	Location: 29
Mentor/Lab: Neeraj Gandhi	Category: Motor
Department: Bioengineering	

Title: A causal study of movement generation using multi-channel recording and patterned microstimulation

Summary: Coordinated activity of neurons is important for many brain functions and behaviours including movement generation. We show that neurons in the superior colliculus a brain region that encodes both sensory input and motor output are de-coordinated during visual processing and coordinate to produce a gaze shift. We verify this observation using causal experiments in which coordinated or uncoordinated patterns of pulses are used to stimulate this region.

Abstract: Sensorimotor transformations are mediated by premotor brain networks whose evolving activities multiplex sensory cognitive and movement-related information. A fundamental question in neuroscience is how the brain resolves activity related to movement generation from prior activity. In the gaze control system visuomotor neurons serve as appropriate substrates to study this question. These neurons are activated both by the onset of a visual stimulus in (visual burst) as well as a saccade to (premotor burst) their response field and are prevalent in the superior colliculus (SC) and frontal eye fields (FEF) critical nodes in the gaze control network. Intriguingly visuomotor neurons also have direct projections to brainstem burst generators that are involved in saccade initiation thus raising the question - why does the high-frequency visual burst not produce a saccade? In other words how does a decoder parse incoming sensorimotor information to guide movement generation? Extant models posit threshold-based gating or low-D population-based readouts as the solution to this demuxing problem. We recently showed using pseudo-population analyses that SC and FEF activity during the visual burst is temporally unstable while regaining stability during the premotor burst (bioRxiv doi: 10.1101/132514) suggesting a combination of high firing rate and population stability as a putative mechanism for movement generation. Here we test these alternative models in a causal framework. We first verified that the temporal stability hypothesis also holds on individual trials by using a linear microelectrode array to record SC population activity in monkeys performing the delayed saccade task. Differences observed in the temporal structure of visual and premotor bursts were similar to those mentioned above. Additionally a linear decoder operating on reduced-D population activity was also able to discriminate between the two bursts. We then explicitly tested the alternative population-based models by applying sub-threshold patterned microstimulation simultaneously across multiple electrode sites in SC. Stimulation patterns were designed to be either stable or unstable on different trials with matched pulse rates across the population. Stable patterns were more likely to evoke saccades and at lower latencies compared to rate-matched unstable patterns. Crucially a linear decoding mechanism was insufficient to explain the differences in stimulation outcomes. This provides a causal demonstration that the temporal structure of instantaneous population activity is the key variable determining movement initiation at least in gaze control.

First Author: Christina Cerkevich (Postdoctoral)	Poster Session: am
Presenting Author: Christina Cerkevich (Postdoctoral)	Location: 30
Mentor/Lab: Peter Strick	Category: Motor
Department: Systems Neuroscience Institute	

Title: How primary is primary motor cortex for the control of vocalization?

Summary: These results indicate that the descending control over laryngeal muscles originates from multiple cortical motor areas. Thus the vocal motor system is characterized by multiple brain areas with the potential for sending parallel commands.

Abstract: Laryngeal muscles play a critical role in enabling vocalization in monkeys and humans. Yet we know surprisingly little about the areas of the cerebral cortex that are involved in the descending control of these muscles. Here we used retrograde transneuronal transport of rabies virus to identify the cortical areas that are most directly connected to the motoneurons of laryngeal muscles in the macaque. This approach identified five cortical areas as the major origin of output to laryngeal muscles. Two of these areas are on the lateral surface of the hemisphere and include the primary motor cortex (M1) and a region that overlaps portions of ventral area 6 (6V) and the motor proisocortex (ProM). Three of these areas are on the medial wall of the hemisphere and include the supplementary motor area (SMA) the rostral cingulate motor area (CMAr) and the ventral cingulate motor area (CMAv). We totaled the surface area of cerebral cortex that is the origin of descending control over laryngeal muscles. Then we assessed the relative contribution of each motor area to laryngeal control. This analysis showed that M1 makes the single largest contribution to laryngeal control (~40%). The next largest output originates from two areas: 6V/ProM (~20%) and CMAr (~20%). In fact taken together the output from these two areas is equal to or greater than that from M1. Significantly smaller output originates from the SMA (~10%) and the CMAv (~6%). These results indicate that the descending control over laryngeal muscles originates from multiple cortical motor areas in the frontal lobe. M1 is the single largest source of cortical control over laryngeal muscles. Even so the majority of the descending control originates from cortical areas outside of M1.

First Author: Matthew Boring (Graduate)	Poster Session: am
Presenting Author: Matthew Boring (Graduate)	Location: 31
Mentor/Lab: Avniel Ghuman	Category: Sensory
Department: Center for Neuroscience	

Title: Investigating the spatiotemporal dynamics of human visual category processing with intracranial EEG

Summary: Regions dedicated to visual object recognition have been studied for decades however the temporal dynamics of this processing are not well understood. Intracranial electroencephalography is a technique that excels in both spatial and temporal resolution. Machine learning was applied to this recording modality to better understand how category level object recognition evolves in the human ventral visual stream.

Abstract: It has been known for centuries that damage to circumscribed brain regions can cause category-specific deficits in perception. This has led to an extensive search to build maps of category selective regions in the brain. Less is known about the spatiotemporal dynamics of visual category processing and the stages of this information processing. To help elucidate the spatiotemporal dynamics of visual object recognition 25 patients with intractable epilepsy were presented images of faces bodies houses hammers words or scrambled objects while intracranial electroencephalography (iEEG) data was collected from a total of 2464 electrodes distributed across the cortex. Multivariate classification and time series analyses were applied to these data to produce movies of the dynamics of category sensitivity across the regions covered by these electrodes. Of these electrodes 195 showed significant decoding accuracy at a conservative statistical threshold for at least one stimulus category at some point after stimulus presentation. Onset of this sensitivity was as early as 100 ms with peak sensitivity at 220 ms and many electrodes in the ventral visual stream continued to show sensitivity beyond 600 ms post stimulus presentation. Object sensitive electrodes had a clear organization with houses represented medially while words and faces were represented laterally. In addition to this several electrodes were sensitive to more than one category and some of these electrodes had different time-courses of sensitivity between categories. Further analyses show the functional connectivity dynamics of these object-sensitive regions (time evolving graphs) and use time series modeling to assess processing stages in a data-driven manner. Taken together these results illustrate important principles regarding the neural information processing dynamics and information flow that underlie visual object processing and recognition.

First Author: Kevin Mohsenian (Graduate)	Poster Session: am
Presenting Author: Kevin Mohsenian (Graduate)	Location: 32
Mentor/Lab: Dr. Neeraj Gandhi	Category: Sensory
Department: Bioengineering	

Title: Population activity in the superior colliculus for saccades to moving targets

Summary: The population activity in the superior colliculus for saccades to moving targets is unknown. We plan to combine neural recordings to be able to estimate the ensemble response for saccades made the amplitude matched locations and compare the activity for different speeds and directions. We will test different saccade vector encoding mechanism that the superior colliculus may employ.

Abstract: The ability to intercept moving targets is crucial for both survival and success. The superior colliculus (SC) a central hub for sensory-motor integration issues the movement command to produce saccadic eye movements. For saccades to stationary targets the SC population activity is characterized as a Gaussian distribution. The SC contributes to the generation of saccades to moving targets also but its exact role in not clear. In particular delays in neural transduction cause the sensory representation of a moving target's position to lag its actual position by 50-100 msec. Target motion during this delay must be accounted for in order to direct action to its future location. Previous work recording single units in the SC reported that some neurons issue the saccade command to a target's location 50-100ms prior to saccade onset. Incidentally other SC neurons seem to account for the neural transduction delay reflecting activity for the executed saccade vector. Our objective here is to determine the population activity of the SC for saccades to moving targets. To address this knowledge gap we recorded neural activity from a rhesus monkey which performed a delayed saccade task. The delay period initial target location target speed (range: 15-45 deg/s) and target direction (inward outward) were varied randomly to elicit saccades with different vectors (amplitude and angle). Trials using stationary targets and moving targets were randomly interleaved. SC population activities of the two trial types were compared through matching the saccade vector performed by the subject. Preliminary results lend support to an alternative view – namely that the SC population activity when the target is moving is not Gaussian. We will assess whether the non-Gaussian population can be used to differentiate between prominent algorithms (weighted vector summation vs. weighted vector averaging) for decoding SC activity for saccade generation.

First Author: Sanjeev Khanna
(Graduate)

Presenting Author: Sanjeev Khanna
(Graduate)

Mentor/Lab: Matthew Smith

Department: Bioengineering

Poster Session: am

Location: 33

Category: Sensory

Title: Correlated variability during eye movement planning in the frontal eye fields and superior colliculus

Summary: Planning an eye movement to a visual stimulus such as looking at a traffic light at an intersection requires the coordination of multiple cells both within and between brain regions. Here we studied how groups of cells in two brain regions responsible for controlling eye movements varied their activity in relation to each other.

Abstract: Trial-to-trial fluctuations in spiking activity which give rise to correlated variability are commonly observed between pairs of neurons in a wide variety of cortical areas. Correlation among a population of neurons has been suggested to impact the amount of information it can represent. This stored sensory information such as a visual stimulus could then be used to guide a motor output such as an eye movement. Very little is known however about the correlated activity in areas that bridge this sensory and motor divide particularly the relationship between correlated activity and behavior. The frontal eye fields (FEF) and superior colliculus (SC) are both considered to be important regions controlling eye movements as both areas contain neurons with a wide variety of response profiles (both visual and motor). This makes them ideal candidates for studying the relationship between correlated activity and the planning and execution of eye movements. We used linear electrode arrays to record from groups of FEF or SC neurons in alert rhesus macaque monkeys performing a conventional memory guided saccade task (FEF) or delayed visually guided saccade task (SC). We measured the spike count correlation (also known as noise correlation) between pairs of simultaneously recorded neurons during the delay period after the visual stimulus was present but before the animal had made an eye movement. We found correlation in this epoch leading up to an eye movement varied depending on the reaction time of the animal's subsequent eye movement in pairs of both SC and FEF neurons. Additionally the relationship between correlation and reaction time was dependent on the direction of the eye movement. This correlation structure shared a number of common features between FEF and SC populations while the observed differences may be understood by considering their different levels in the oculomotor hierarchy.

First Author: Patricia Stan (Graduate)	Poster Session: am
Presenting Author: Patricia Stan (Graduate)	Location: 34
Mentor/Lab: Sandra Kuhlman	Category: Sensory
Department: Neurobiology	

Title: Function of tuning diversity in visual coding

Summary: Neurons in primary visual cortex (V1) are diverse in their orientation selectivity (their response to a select number of orientations of a bar) with some neurons responding to few orientations (sharply tuned) while others respond to many orientations (broadly tuned); our goal is to discover what the role of this diversity is in visual coding and how experience may affect this diversity. Sharply tuned neurons are shown to be important for detecting edges but the role of broadly tuned neurons is unclear. Our studies indicate that broadly tuned neurons are important for processing stimuli containing complex features.

Abstract: Neurons in primary visual cortex (V1) are diverse in their orientation selectivity – their response to a select number of orientations of a bar. Computational modeling studies indicate that this diversity is important for the discriminability of natural scenes with neurons of different orientation selectivity playing different roles. While the more commonly studied two-thirds of V1 neurons which are sharply tuned for orientation (respond to few orientations; orientation selectivity index OSI is > 0.44) are thought to play a role in edge detection the role of neurons broadly tuned for orientation (respond to many orientations; OSI < 0.3) remains unclear. We hypothesize that neurons broadly tuned for orientation are important for processing stimuli containing complex features. To examine this we used large field of view calcium imaging in awake mice to compare the responses of excitatory neurons (upwards of 400 neurons per imaging session 9 imaging sessions from 7 mice) to classic sinusoidal gratings versus complex stimuli (hyperbolic and spiral stimuli created from hyperbolic and polar coordinate systems) at a range of orientations and spatial frequencies (SF). Using greedy decoding algorithms we designed tasks to identify ensembles of neurons best at performing edge detection (decoding grating orientation) or orientation-invariant attribute detection of complex stimuli (decoding hyperbolic or spiral SF). We found that the properties of neurons comprising the ensembles best at decoding hyperbolic and spiral SF are distinct from those associated with edge detection (OSI for grating = 0.57 hyperbolic = 0.24 and for spiral = 0.22) with some ensemble neurons having no response to gratings (13-17% of the neurons within the high-accuracy complex SF ensembles). To identify the response properties that give rise to high accuracy we used linear regression analysis and determined properties that were significantly correlated with accuracy (Wilcoxon rank sum test of median fit coefficients) for each task. As expected decoding accuracy of grating orientation was positively correlated with sharpness of orientation tuning (p<0.01) and negatively correlated with sharpness of SF tuning (p<0.01). In contrast decoding of hyperbolic SF was negatively correlated with sharpness of orientation tuning (p<0.05) and positively correlated with sharpness of SF tuning (p<0.01). Similarly to decoding of hyperbolic SF decoding of spiral SF was positively correlated with sharpness of SF tuning (p<0.05) yet these ensembles were largely non-overlapping (spiral-hyperbolic ensemble overlap=14.4%). In summary we identified ensembles of neurons useful for encoding orientation-invariant features of complex stimuli at the earliest stages of visual cortical processing and found that these neurons tend to be broadly tuned for orientation. Furthermore there appears to be specialization in V1 for hyperbolic versus polar coordinate systems. Future studies will examine how altered visual experience affects the distribution of orientation selectivity and other response properties.

First Author: Manoj Kumar (Postdoctoral)	Poster Session: am
Presenting Author: Manoj Kumar (Postdoctoral)	Location: 35
Mentor/Lab: Thanos Tzounopoulos	Category: Sensory
Department: Department of Otolaryngology	

Title: Cell-specific gain modulation by synaptically released zinc in cortical circuits of audition

Summary: We used widefield transcranial imaging of the genetically-encoded calcium indicator GCaMP6 to identify the effects of synaptic zinc on populations of specific neuronal types in the auditory cortex and two-photon imaging to interrogate the effects of zinc on individual layer 2/3 neurons. Our results highlight synaptic zinc as a novel modulator of cortical responses to sound.

Abstract: In many excitatory synapses mobile zinc is found within glutamatergic vesicles and is coreleased with glutamate. Ex vivo studies established that synaptically released (synaptic) zinc inhibits excitatory neurotransmission at lower frequencies of synaptic activity but enhances steady state synaptic responses during higher frequencies of activity. However it remains unknown how synaptic zinc affects neuronal processing in vivo. Here we imaged the sound-evoked neuronal activity of the primary auditory cortex in awake mice. We discovered that synaptic zinc enhanced the gain of sound-evoked responses in CaMKII-expressing principal neurons but it reduced the gain of parvalbumin- and somatostatin-expressing interneurons. This modulation was sound intensity-dependent and in part NMDA receptor-independent. By establishing a previously unknown link between synaptic zinc and gain control of auditory cortical processing our findings advance understanding about cortical synaptic mechanisms and create a new framework for approaching and interpreting the role of the auditory cortex in sound processing.

First Author: Nathan Vogler (Graduate)	Poster Session: am
Presenting Author: Nathan Vogler (Graduate)	Location: 36
Mentor/Lab: Thanos Tzounopoulos	Category: Sensory
Department: Otolaryngology	

Title: Activity-dependent Plasticity of Synaptic Zinc Signaling in the Dorsal Cochlear Nucleus - a Novel Synaptic Plasticity Mechanism

Summary: Many synapses in the brain contain zinc which functions as a neurotransmitter. Synaptic zinc is modulated by sensory experience but the mechanism of how this occurs has been unknown. This research demonstrates that zinc signaling is modulated by synaptic activity and identifies crucial components of the mechanism underlying this process.

Abstract: In many excitatory synapses mobile zinc is found within glutamatergic vesicles and is co-released with glutamate. Ex vivo studies established that synaptically released (synaptic) zinc inhibits excitatory neurotransmission at lower frequencies of synaptic activity but enhances steady state synaptic responses during higher frequencies of activity (Mcallister & Dyck 2017; Kalappa et al. 2017). Recent in vivo studies established that synaptic zinc modulates cortical auditory processing by enhancing the gain of sound-evoked responses in auditory cortical principal neurons and reducing the gain of cortical interneurons (Anderson et al. eLife in press). Zinc-mediated modulation of neurotransmission and presynaptic zinc levels are modulated by activity in many brain areas such as somatosensory and visual cortex the retina and the dorsal cochlear nucleus (DCN) an auditory brainstem nucleus (Nakashima & Dyck 2009; Li et al. 2017; Kalappa et al. 2015). However the signaling mechanisms underlying this plasticity remain unknown. To study these mechanisms we employed in vitro electrophysiological recordings in DCN brain slices. Application of the extracellular zinc chelator ZX1 (100μM) potentiates AMPAR and NMDAR EPSCs evoked by stimulation of parallel fibers demonstrating AMPAR/NMDAR inhibition by synaptic zinc. High frequency stimulation (HFS 3 x 100 Hz) of parallel fibers eliminates potentiation by ZX1 indicating activity-dependent plasticity of zinc-mediated inhibition (zinc plasticity). Zinc plasticity is blocked by the intracellular calcium buffer BAPTA (10mM) as well as the metabotropic glutamate receptor (mGluR) antagonist MCPG (500μM) and the Type 1-specific mGluR antagonists MPEP (4μM) and LY367385 (100μM). Furthermore application of CPA (20μM) an inhibitor of SERCA ATPase which depletes calcium from intracellular stores is sufficient to induce zinc plasticity. Application of the Type 1 mGluR agonist DHPG at a low concentration (5μM) also eliminates zinc-mediated inhibition; however DHPG at a higher concentration (50μM) increases zinc-mediated inhibition. Our results demonstrate the activity-dependent plasticity of zinc-mediated inhibition at DCN parallel fiber synapses. Zinc plasticity involves activation of Type 1 mGluRs and release of calcium from intracellular stores. Furthermore our results suggest a role for mGluR signaling in the bidirectional modulation of zinc plasticity. Together these results reveal a novel synaptic plasticity mechanism that modulates zinc-mediated inhibition of glutamatergic neurotransmission.

First Author: Shi Tong Liu (Graduate)	Poster Session: am
Presenting Author: Shi Tong Liu (Graduate)	Location: 37
Mentor/Lab: Srivatsun Sadagopan	Category: Sensory
Department: Bioengineering	

Title: Optimal features for auditory recognition

Summary: Using a theoretical information approach we extracted a set of auditory features that can be used to identify vocalizations types from any given marmoset vocalizations. These features also closely correspond to previously found nonlinear neural responses in marmoset A1 suggesting that the tuning properties of neurons in higher auditory cortical stages are likely the result of goal-directed optimization.

Abstract: A central challenge in auditory neuroscience is to understand how observed patterns of neural activity in the auditory system relate to behavior. For example neurons in primary (A1) as well as higher auditory cortical areas exhibit highly nonlinear and surprisingly specific tuning properties but our understanding of these responses is only at a descriptive level and the critical question of how these responses might support behavior remains unresolved. Here we show that nonlinear A1 responses encode essential features for the classification of ethologically-relevant sounds such as conspecific vocalizations (calls). In vocal animals increasing neural resources are committed for the processing of calls as one ascends the auditory processing hierarchy. Therefore the categorization of call types is a reasonable computational goal for the auditory cortex in these animals. We asked using a theoretical information maximization approach how this goal can be best accomplished. We used marmoset vocalizations as our experimental model. First we transformed the vocalizations into spectrotemporal patterns of auditory nerve activity (cochleagrams) using a highly realistic model of the auditory nerve. Based on an earlier model for visual classification we then randomly generated a large number of features or spectrotemporal snippets from these cochleagrams. We used a greedy-search algorithm to choose the most informative and least redundant feature set for call categorization. We found that call categorization could be accomplished with high accuracy using just a small number of features. Highly informative features tended to be of intermediate size and complexity. Most interestingly the responses of model feature-selective neurons predicted nonlinear neural responses in marmoset A1 in astonishing detail. These results demonstrate that the auditory cortex uses a mid-level feature based strategy for the recognition of complex sounds. These results further suggest that the tuning properties of neurons in higher auditory cortical stages are likely the result of goal-directed optimization.

First Author: Amanda Henton (Graduate)	Poster Session: am
Presenting Author: Amanda Henton (Graduate)	Location: 38
Mentor/Lab: Thanos Tzounopoulos	Category: Sensory
Department: Otolaryngology	

Title: Cell-Specific Noise-Induced Changes in the Intrinsic Properties of Auditory Cortical Projection Neurons

Summary: Tinnitus is a condition where a sound is perceived where no sound is present in the external environment we have developed a new behavioral model to test the presence of tinnitus in mice. While some subcortical mechanisms of tinnitus are known tinnitus' mechanisms in cortex are unknown. Here we found cell type-specific changes in projection neurons in auditory cortex after noise exposure.

Abstract: Tinnitus is a condition in which a sound is perceived when no sound is present in the external environment. Among its causes acoustic overexposure is thought to be the most common. Tinnitus is becoming increasingly prevalent in older adults with hearing loss and in active duty military members that may be routinely exposed to loud sound. However since tinnitus is the perception of a sound that is absent from the external environment it presents many challenges to objectively evaluate its presence or severity in humans or in animal models. Here we have developed a mouse model of tinnitus that utilizes operant training. With this model it is possible to classify noise exposed mice into two groups those that develop tinnitus and those that are resilient. While recent research has shown evidence for maladaptive changes associated with the initiation of tinnitus in subcortical areas the mechanisms underlying tinnitus maintenance in cortex the likely site of perception remain largely unknown. Here we investigated the changes in intrinsic properties of specific subpopulations of projection neurons in auditory cortex pyramidal tract (PT) which project to the inferior colliculus and auditory brainstem and intratelencephalic (IT) neurons which project to the contralateral cortex. After noise exposure whereas no changes were found in the intrinsic properties of IT neurons the resting membrane potential of PT neurons in auditory cortex is significantly lower than controls. These findings may reveal a novel cell-specific site of modulation in auditory cortex after noise exposure and in pathological conditions such as tinnitus.

First Author: Pilar Montes Lourido (Postdoctoral)	Poster Session: am
Presenting Author: Pilar Montes Lourido (Postdoctoral)	Location: 39
Mentor/Lab: Srivatsun Sadagopan	Category: Sensory
Department: Neurobiology	

Title: Emergence of selectivity and invariance in primary auditory cortex

Summary: In real world conditions the sounds that we hear are degraded by environmental factors such as noise echoes or other speakers. Our auditory system is able to maintain sound perception despite all these disturbances. This study is aimed at understanding how the brain accomplished this feat.

Abstract: Humans and vocal animals use vocalizations to communicate and interact with members of their species. Real-world environments add noises echoes and other sounds to the intended message degrading its acoustic content. However we can maintain stable sound perception independent of listening conditions. We aim to determine the neural mechanisms by which stable sound perception can be achieved. To address this question in the context of natural behaviors we use Guinea pig (GP) vocalizations as an experimental model. Previous studies in GPs have shown that at the level of the inferior colliculus and thalamus few neurons show selective responses for individual vocalization categories. In primary and secondary cortical areas more neurons become selective for particular vocalization categories. It is not known however at which stage of the auditory hierarchy this selectivity arises and how it is preserved or changed in the presence of real-world distortions. Here we first tested if GPs can perceive vocalizations presented in a wide range of noisy environments using pupillometry as a behavioral readout. This allowed us to determine the GP's threshold for detecting a vocalization in noise. We then recorded single-unit activity in the medial geniculate body (MGB) and auditory cortex (A1) of awake GPs passively listening to vocalizations in different listening conditions. We discovered that neurons in MGB and thalamorecipient A1 layers (A1 L4) have low selectivity for vocalization categories and are more susceptible to acoustic distortions. In contrast superficial layers of A1 (A1 L2/3) were highly selective for vocalizations and more invariant to distortion. These data demonstrate that both vocalization selectivity and invariance to listening conditions co-emerge in A1 L2/3. These results suggest that a dense representation of complex sounds in A1 L4 is transformed into an invariant and sparse representation in A1 L2/3.

First Author: Tobias Teichert (Faculty)	Poster Session: am
Presenting Author: Tobias Teichert (Faculty)	Location: 40
Mentor/Lab: Teichert	Category: Sensory
Department: Psychiatry and Bioengineering	

Title: Tracking the gradual formation and decay of auditory sensory memory using behavior and concurrent EEG recordings in macaque monkeys

Summary: For several seconds past sounds are stored as a gradually decaying memory trace. This trace plays a fundamental role for many auditory functions such as speech perception yet remains unclear how it is implemented in the brain. This work tests the hypothesis that each sound reduces the signaling capacity of neurons that respond to it and thus leave a negative trace of past sounds that persists until the signaling capacity has been replenished over the course of several seconds.

Abstract: Background. For several seconds auditory information is passively stored in auditory sensory memory. Despite the importance of auditory sensory memory for many aspects of auditory function its neural mechanisms are still a matter of debate. However it has been noted that the amplitude of the auditory evoked N1 which is reduced immediately after a tone has been processed recovers back to baseline at the same rate at which information decays from auditory sensory memory. Here we tested the hypothesis that amplitudes of auditory evoked potentials (AEPs) elicited by a specific tone are smaller if that tone is encoded more strongly in auditory sensory memory. Methods. To that aim we recorded AEPs from 32 cranial EEG electrodes while macaque monkeys performed a novel delayed pitch-discrimination task designed to track the dynamic formation and decay of auditory sensory memory. In the task animals listened to sequences of standard tones and released a lever when they identified a pitch-deviant target tone. The stimulus-onset asynchrony (SOA) of consecutive tones varied randomly between 0.250 and 12 sec. The target could occur between sequence positions 2 and 13. The frequency-difference between standard and target (ΔF) varied between 0 and 1.2 octaves. On catch trials (ΔF=0) animals were rewarded for not releasing the lever. Results. Target detection rate increased with ΔF. The slope of the corresponding psychometric function was used to quantify discrimination performance as a function of SOA and the number of preceding standards. Preliminary data showed that discrimination performance gradually increased with repetition number and decreased with SOA. Comparison to behavior in homolog signal detection tasks without sensory memory component suggests that changes of performance in the discrimination task reflect the gradual strengthening of sensory memory with repetition and its gradual decay during periods of silence. The hypothesis that small AEPs are a marker of strong memory encoding thus predicted that AEP amplitude would be small for short SOAs and after many repetitions. Indeed several AEPs such as the P31 and the N85 –the presumed monkey homolog of the N1– were smallest for the shortest SOAs. However contrary to the prediction AEP amplitudes generally increased with stimulus repetition. Both effects shared similar timing and topography with one key exception: between 40 and 60 ms after tone-onset fronto-central electrodes (human Fz homolog) encoded SOA while the effect of repetition number was either completely absent or substantially weaker. Interestingly ERPs at the same latency and topography were reduced by stimulus-specific adaptation in a passive listening task. Conclusion. Taken together these findings suggest a specific role for this fronto-central EEG component in stimulus-specific adaptation and sensory memory. However additional quantitative analyses are needed to link this component more closely to performance in the delayed tone-discrimination task and single-cell responses in auditory cortex.

First Author: Kristen Smith-Edwards (Postdoctoral)	Poster Session: am
Presenting Author: Kristen Smith-Edwards (Postdoctoral)	Location: 41
Mentor/Lab: Davis	Category: Sensory
Department: Neurobiology	

Title: Mapping Functional Connections in the Gut's Brain

Summary: Using genetic techniques that make cells light up when they are active we can watch neural activity within the colon to understand how these cells communicate with each other and coordinate the movement of fecal matter through the digestive system.

Abstract: Kristen M. Smith-Edwards Sarah A. Najjar Kathryn A. Albers Brian M. Davis The gut is equipped with its own local nervous system the enteric nervous system ('the gut's brain') and similar to the central nervous system there are neuronal subpopulations responsible for detecting sensory information integrating and processing this information and providing signals for motor execution. In the colon these neuronal populations communicate with each other and to other non-neuronal cells (e.g. interstitial cells of Cajal ICC and smooth muscle cells) to coordinate movement of fecal matter however up to 70% of people will experience gastrointestinal motility dysfunction at some point in their lives. Mapping the functional connections among enteric subpopulations of cells would provide the means to regulate gastrointestinal functioning. Toward this end we used mice that express GCaMP in all cells to image spontaneous and evoked calcium signals in real-time using an ex vivo colon preparation. Different patterns of spontaneous activity were observed in enteric neurons and ICC. Twenty-one percent of neurons in a given myenteric ganglion (21.0 ±1.6% N=3 mice n=56 ganglia) displayed irregular spontaneous calcium transients that did not appear to be synchronized whereas ICC located in deeper layers of the colon exhibited rhythmic synchronized calcium oscillations that occurred 11.7±1.1 cycles per minute (N=3 mice n=19 fields of view). Interestingly activation of enteric neurons by electrical stimulation of the colon slowed ICC oscillations to 74.0±6.0% of baseline indicating neuronal modulation of ICC pacemaker activity. Lastly stimulation of the colon either rostral or caudal to the myenteric ganglion in the imaging field activated different subsets of neurons with minimal overlap (24.6±3.3% N=2 mice n=7 ganglia) suggesting discrete ascending versus descending interganglionic communication in the colon. Future studies will probe into the molecular identity of the various functional subpopulations of enteric neurons described here using immunohistochemistry pharmacology and optogenetic techniques.

First Author: Sarah Najjar (Graduate)	Poster Session: am
Presenting Author: Sarah Najjar (Graduate)	Location: 42
Mentor/Lab: Dr. Kathryn Albers	Category: Sensory
Department: Neurobiology	

Title: Sensory Innervation of the Enteric Nervous System: A Two-Way Street?

Summary: This study investigates the pathways connecting the gut's own nervous system (called the enteric nervous system) to the central nervous system. Understanding these connections will help us to understand the origin of and treatments for gastrointestinal disorders.

Abstract: The enteric nervous system (ENS) consists of a mesh-like network of neurons intrinsic to the gastrointestinal (GI) tract which controls GI function. Extrinsic sensory neurons innervating the gut also have a key role in GI processes as they initiate autonomic reflexes and convey sensory information (e.g. pain and bloating). Thus far it has been difficult to parse out the function of these sensory neurons due to the dense autonomic innervation of the gut (in addition to sensory innervation). Our lab has overcome this limitation by employing calcium imaging techniques to explore the connectivity between the ENS and its extrinsic sensory inputs. Using mice that express GCaMP6 in all cells we developed an ex vivo preparation in which the activity of ENS neurons and sensory neurons in L6 dorsal root ganglia (DRG) can be recorded. We recorded L6 sensory neuron activity in response to stimulation of the colon. We then applied electrical stimulation to the L6 DRG and imaged activity in the myenteric ganglia of the ENS. Surprisingly we found that 20 Hz stimulation of the DRG resulted in calcium signals in 17.1±2.8% of cells per myenteric ganglion and the average calcium influx (ΔF/F) was 24.8±5.5 (n=54 cells). This DRG stimulation also resulted in smooth muscle contraction in the colon 1.19±0.16 seconds after application of stimulus (and usually after activation of the myenteric ganglia cells). Finally we found that electrical stimulation of the DRG impacted the activity of the gut's non-neuronal pacemaker cells in the sub-mucosal plexus (interstitial cells of Cajal; ICCs). The 20 Hz stimulus decreased the frequency of ICC oscillations to 90±1.8% of baseline (or by 1.3±0.3 cycles per minute). Taken together these data indicate extrinsic sensory neurons have a significant efferent role in the ENS. Our imaging methods will enable further exploration of ENS-sensory neuron connectivity and how these interactions may become disordered in pathological states (e.g. visceral pain associated with irritable bowel syndrome and inflammatory bowel disease).

First Author: Emanuel Loeza (Postdoctoral)	Poster Session: am
Presenting Author: Emanuel Loeza (Postdoctoral)	Location: 43
Mentor/Lab: Michael Gold	Category: Sensory
Department: Neurobiology	

Title: Peripheral GABAA receptors regulate colonic afferent excitability

Summary: Peripheral GABAA receptors can modulate the colonic afferent activity

Abstract: The role of GABAA receptors located at central terminals of primary afferents fibers in the regulation of afferent input to the superficial dorsal horn has been well established. However there is evidence that GABAA receptors are trafficked to peripheral terminals as well with at least some evidence suggesting that in the presence of tissue injury these receptors are functional. Because there are several sources of GABA in the colon in the absence of tissue injury we hypothesized that the excitability of colonic afferents is established at least in part via GABA acting at GABAA receptors on the peripheral terminals of these afferents. To test this hypothesis we utilized an in vitro mouse colorectum-pelvic nerve preparation in which GABAA receptor agonists and antagonists could be applied to the receptive field of functionally identified afferent fibers as a means of assessing changes in stimulus response properties. Using single-fiber recordings of the pelvic nerve we found that the application either GABA or muscimol results in both an increase in the amount of colon stretch required to evoke an action potential a decrease in the number of stretch-evoked action potentials. Both agonists also increased the electrical-threshold and decreased the apparent conduction velocity of the evoked action potential. Conversely the GABAA-antagonist bicuculline or blocker picrotoxin decreased the stretch threshold and increased the number of stretch-evoked action potentials. Picrotoxin also increased the apparent conduction velocity of the electrical stimulation evoked action potential evoked by electrical stimulation. These results suggest that peripheral GABAA receptors are not only present and functional in the peripheral terminals of colonic afferents but that activation of these receptors via endogenous GABA release contributes to the establishment of colonic afferent stimulus-response properties. These results raise the intriguing possibility that approaches to selectively increase peripheral GABAA receptor signaling could be used to treat visceral pain in the absence of central nervous system side effects. Work supported by NIH grant R01 DK107966.

First Author: JORGE PINEDA (Postdoctoral)	Poster Session: am
Presenting Author: JORGE PINEDA (Postdoctoral)	Location: 44
Mentor/Lab: MICHAEL GOLD	Category: Sensory
Department: DEPARTMENT OF NEUROBIOLOGY	

Title: Characterization of chemotherapeutic-induced visceral neuropathy

Summary: Cancer survivors have reported the presence of pain in different areas of the body after a chemotherapeutic treatment. We study the possible relation between cancer treatment and the development of visceral pain.

Abstract: Chemotherapeutic-induced peripheral neuropathy (CIPN) characterized by numbness tingling and ultimately pain in the hands and feet remains the primary dose-limiting side effect of some of the most effective anti-cancer drugs. But while the primary focus of CIPN research has been on the somatic nervous system clinical data suggest a variety of persistent visceral symptoms may have the most deleterious impact on the quality of life in cancer survivors. Both because of the nature of the persistent symptoms and our recent data suggesting that unique features of a subpopulation of somatic afferents make them particularly vulnerable to chemotherapeutics we hypothesized that the persistent visceral symptoms reflect a chemotherapeutic-induced “visceral” neuropathy (CIVN). To test this hypothesis we assessed changes in visceral sensory neurons (the vagus and nodose ganglia) and the enteric nervous system in rats a week after the last of six IV infusions of the combination of paclitaxel (2 mg/kg) and carboplatin (30 mg/kg) administered over three weeks. Changes in somatic afferents were used for comparison. Combination- but not vehicle-treated rats developed mechanical and cold sensitivity within the first week of drug administration that did not resolve. Combination-treatment was also associated with a significant (~50%) reduction in the conduction velocity of A- and C-fibers in both sciatic and vagal nerves. The chemokine MCP-1 was increase in a subpopulation of neurons in both L4/L5 dorsal root ganglia (DRG) and nodose ganglia. There was also an increase in the mitochondria protein TOM-20 in a subpopulation of DRG and nodose neurons. Our results are consistent with our initial hypothesis. Whether the same mechanism(s) are responsible for the damage to visceral and somatic afferents remains to be determined. Identification of the mechanisms responsible for the damage to visceral neurons however may suggest novel treatments for patients suffering from these persistent symptoms. Work was supported by Grant R01 DK107966

First Author: Junichi Hachisuka (Faculty)	Poster Session: am
Presenting Author: Junichi Hachisuka (Postdoctoral)	Location: 45
Mentor/Lab: Sarah Ross	Category: Sensory
Department: Neurobiology	
Title: Research Assistant Professor	
Summary: Wind-up is involved in pain amplification. We found a novel mechanism of wind-up that is caused by reverberating activation of the excitatory interneuron circuit in the spinal cord.	
Abstract: Wind-up is a frequency-dependent increase in the excitability of spinal cord neurons and could be involved in pain amplification of chronic pain. However the neural circuit basis for wind-up in lamina I spinoparabrachial (SPB) neurons is mostly unknown. We found a subset of these SPB neurons shows wind-up by repetitive root stimulation. We hypothesized that an excitatory interneuron network mediates wind-up. Supporting this idea we found repetitive optogenetic activation of NtsCre expressing excitatory interneurons induce increase of action potentials in lamina I SPB neurons. Root-evoked wind-up was completely blocked by silencing NtsCre neurons with activation of archaerhodopsin. In addition we found that NtsCre neurons form an excitatory network that causes reverberating activity and enhance excitatory input to the lamina I SPB neurons. These data indicate that excitatory interneuron network is involved in sensory augmentation in lamina I SPB neurons.	

First Author: Michael Chiang (Graduate)	Poster Session: am
Presenting Author: Michael Chiang (Graduate)	Location: 46
Mentor/Lab: Sarah Ross	Category: Sensory
Department: Neurobiology	

Title: Neural pathways that convey separable aspects of the pain experience

Summary: Pain affect is believed to arise from the spino-parabrachial pathway via the lateral parabrachial nucleus (LPBN). However the role of distinct projections from the LPBN in the pain response is poorly understood. We use viral tracing and optogenetic methods to reveal unique behavioral roles for the different lateral parabrachial outputs in the generation of the pain experience.

Abstract: Pathological pain is a widespread condition that affects one in four Americans. Although opioids have long been used for their analgesic effects in pain management these drugs have severe adverse effects. An alternative approach with reduced adverse effects is delivering pain therapeutics to modulate neural circuitry within the brain responsible for contributing to the affective component of pain perception. Pain affect is believed to arise from the spino-parabrachial pathway via the lateral parabrachial nucleus (LPBN). However the role of distinct projections from the LPBN in the pain response is poorly understood. Here we show that the LPBN projects to six major targets in the brain: the insular cortex bed nucleus stria terminalis central amygdala hypothalamus paraventricular thalamus and periaquedutal gray. Using optogenetic approaches to target specific pathways we find that the two amygdala targets (central amygdala and dorsolateral bed nucleus stria terminals) are highly aversive as measured in a real time place preference assay. In contrast projections from the LPBN to hypothalamus mediate changes in heart and respiratory rates. Finally projections from the LBPN to the periaqueductal gray mediate the descending modulation of pain as measured by response latency to heat stimuli. These findings suggest that different components of a pain response are encoded within distinct pathways arising from the LPBN. Interestingly anatomical tracing of LPBN pathways indicate that spatially and neurochemically distinct subpopulations of LPBN neurons differentially project to subsets of recipient brain regions suggesting that LPBN subsets convey different aspects of pain perception. Identifying these will provide insight in our understanding of how the brain integrates nociceptive stimuli to generate pain perception. Furthermore this understanding can potentially contribute to the development of novel therapeutic agents that target a specific neural pathway underlying clinically relevant aspects of pain such as those neural pathways conveying the unpleasantness of pain.

First Author: Ameya Nanivadekar (Graduate)	Poster Session: am
Presenting Author: Ameya Nanivadekar (Graduate)	Location: 47
Mentor/Lab: Rehab Neural Engineering Labs/Lee Fisher	Category: Sensory
Department: Bioengineering	

Title: Modulation of phantom limb pain using epidural stimulation of the cervical dorsal spinal cord

Summary: Electrical stimulation of the cervical dorsal spinal cord can result in acute and sub-chronic changes in the intensity and incidence of phantom limb pain in upper limb amputees.

Abstract: Introduction: Pain is a common comorbidity of conditions such as peripheral nerve injury substance-induced neuropathy and trauma. Nearly 1.5 billion people worldwide suffer from chronic pain with the estimated cost of health care nearly $275 billion. The mechanisms of neuropathic pain are poorly understood and its evaluation in humans is complex because most stimuli required to induce neuropathic pain produce irreversible damage. Recent evidence suggests that the incidence of chronic phantom limb pain can be regulated by delivering sensory feedback that is relevant to the amputated limb. This study aims to determine whether cervical spinal root stimulation to elicit sensations localized to the amputated arm can also result in concomitant changes in PLP Methods: All procedures were approved by the University of Pittsburgh Institutional Review Board and the US Army Human Research Protection Office. Two study participants were implanted with three 8 or 16 contact spinal cord stimulation leads (Boston Scientific) in the lateral epidural space of the cervical spinal cord. Stimulation electrode amplitude frequency and pulse width were varied across trials. The location intensity and modality of the evoked percepts was recorded. The intensity of PLP was recorded on a visual analog scale (VAS) after every stimulation trial. Additionally the McGill Pain Questionnaire (MPQ) was administered on a weekly basis and again one month following explantation. The leads were explanted after 2-4 weeks. Results: A total of 1493 trials evoked localized sensations of which 580 PLP episodes were reported (38.9%) at a mean intensity of 2.5 ± 1.9 on the VAS. For the 115 electrodes that evoked a sensation stimulation amplitude and pulse width were related to the intensity and incidence of PLP respectively. Furthermore a clinically significant (>5 points) reduction in PLP was observed on the MPQ in subject 1 (9 points) and subject 2 (8 points) at 1-month follow-up. Additionally a strong correlation between the modality of stimulation evoked non-PLP sensation and the intensity of PLP reported was observed. Conclusion: This study suggests that stimulation amplitude and pulse width may modulate the intensity and frequency of a PLP episode. We further observed time-dependent PLP modulation such that the immediate post-stimulation phase was associated with increased PLP that may be coupled to a long-term reduction in PLP.

First Author: Heather Bruett (Graduate)	Poster Session: am
Presenting Author: Heather Bruett (Graduate)	Location: 48
Mentor/Lab: Dr. Marc Coutanche LeNS Lab	Category: Brain Models and Systems
Department: Psychology	
Title: The Role of Inter-region Information Synchrony in Processing Visual Stimuli	
Summary: We examined how scenes are processed through connections between different regions of the brain.	
Abstract: The brain processes the many aspects of visual stimuli via the coordinated activity of a number of relevant regions. The processing targets of these regions can be uncovered by “decoding” multivoxel activity patterns which can represent subtle distributed information. An approach that examines the timeseries of pattern discriminability –informational connectivity– can help determine which regions contain information in the same trials - in other words which regions are acting in synchrony. I will present fMRI data that was analyzed via multivariate analysis tools and informational connectivity to determine how information synchrony plays a role in processing scenes and objects. We ask how regions within the scene and object processing networks can decode scenes and objects from “pseudo-scenes” which contain certain elements present in typical scenes but lack other visual components. We find that the strength of informational connectivity within these networks differs based on the object or scene discriminations examined.	

First Author: Yuanning Li (Graduate)	Poster Session: am
Presenting Author: Yuanning Li (Graduate)	Location: 49
Mentor/Lab: Avniel Ghuman	Category: Brain Models and Systems
Department: Neurological Surgery	

Title: Neurodynamics of expression coding in human fusiform

Summary: Using intracranial EEG data from human subjects and multivariate pattern analysis techniques we showed that facial expression information can be decoded from the neural activity in different subdivisions of human fusiform cortex at different stages of the process. This suggests that fusiform activity may contribute to the representation of the structural difference between facial expressions and the posterior and anterior fusiform are dynamically involved in distinct stages of facial information processing.

Abstract: Face processing is mediated by a network involving multiple distributed areas in the brain with the occipital face area (OFA) fusiform face area (FFA) and posterior superior temporal sulcus (pSTS) considered the core nodes of the network. Results suggest that OFA is primarily involved in early perception of facial features FFA is mainly involved in the processing of the static aspects of faces and pSTS is mainly involved in the processing of the dynamic aspects of faces. Based on these results the first models of the neural basis of face processing posited that pSTS codes for expression and FFA codes for identity. Recently several neuroimaging studies have suggested that the FFA is involved in the processing of facial expressions and recent models have posited that the FFA is involved in structural encoding of face expression. To mediate between these hypotheses we recorded intracranial electroencephalography (iEEG) data from 19 patients with electrodes in the OFA FFA and/or pSTS during face expression perception. Using pattern classification techniques our results confirmed the existence of facial expression encoding in the fusiform area. At the early stage of visual information processing (50-250 ms after stimulus onset) neural activity from posterior fusiform area contains facial expression information; and at the late stage of visual processing (250-450 ms after stimulus onset) neural activity from anterior fusiform area contains facial expression information. In addition facial expression information is seen in OFA and pSTS at the early stage of the process. Notably the effect size of fusiform encoding of facial expressions is much smaller than the encoding for facial identity. Taken together these results suggest that fusiform activity may contribute to the representation of the structural difference between facial expressions and the posterior and anterior fusiform are dynamically involved in distinct stages of facial information processing.

First Author: Andrew Papale (Postdoctoral)	Poster Session: am
Presenting Author: Andrew Papale (Postdoctoral)	Location: 50
Mentor/Lab: Bryan M. Hooks	Category: Brain Models and Systems
Department: Neurobiology	

Title: Corticostriatal projections map the organization of inter-area corticocortical connectivity

Summary: The motor system relies on convergence of sensory and motor inputs from cortex to subcortical structures such as the motor system's basal ganglia in order to develop motor skills. In this work we study the connections from cortex to basal ganglia for different types of cortical neurons.

Abstract: A leading circuit model of corticostriatal connectivity is that cortical motor regions form parallel functional loops through the basal ganglia. This model explains the pattern of projections from cortical areas to different regions of striatum and provides a basis for classifying subdivisions of striatum based on divergence of cortical inputs. We tested the generality of this model by examining striatal projections from layer-specific subtypes of pyramidal neurons. Mice expressing Cre in either intratelencephalic layer 5A or pyramidal tract layer 5B were injected with three different Cre-dependent fluorescent viral vectors in primary somatosensory primary motor secondary sensory and frontal cortical areas. Following sectioning and imaging images were aligned to a reference atlas using BrainMaker software (MBF Bioscience). Axonal projections in the striatum were then assessed and compared with corticocortical projections. Voxel fluorescence was correlated in striatum across injection sites to look for patterns of projections across cortical input structures. Clustering of fluorescence in striatum showed distinct clusters that were well-matched with cortical input. For example primary motor and primary sensory areas clustered together. Examining correlations across the dorsoventral rostrocaudal and mediolateral dimensions of striatum suggested a distinct anterior/medial region of the striatum where all areas of the sensorimotor system converged. Differences in the precision of projections to striatum emerged when looking at intratelencephalic layer 5A versus pyramidal tract layer 5B neurons. 3D K-means clustering of striatal voxel fluorescence suggested clear subdivisions of the striatum consistent with pre-existing classifications. These findings are discussed in light of the parallel functional loop theory of basal ganglia.

First Author: Corentin Massot (Postdoctoral)	Poster Session: am
Presenting Author: Corentin Massot (Postdoctoral)	Location: 51
Mentor/Lab: Neeraj J. Gandhi	Category: Brain Models and Systems
Department: bioengineering	

Title: Laminar Organization of the Spiking Activity in the Superior Colliculus

Summary: The superior colliculus plays a major role in oculomotor sensorimotor transformation. Here we show that SC has a laminar organization of its spiking activity. This organization may reflect a network architecture suited for realizing the sensorimotor transformation.

Abstract: The superior colliculus (SC) plays a major role in transforming sensory signals that register a target into motor commands that produce an eye movement to the stimulus. However the underlying network activity that produces the sensorimotor transformation is not well understood. The sensory and movement responses are represented by two bursts of activity across the different layers of SC. Previous studies have shown that neurons in SC can be grouped according to their spiking activity during delayed saccade tasks. However is there also a laminar organization of the spiking activity in SC? Here we addressed this question by recording populations of neurons using a 16-channel laminar probe in SC of two rhesus monkeys performing randomly interleaved delayed visually-guided and memory-guided saccades. The electrode penetration spanned all layers of SC and was orthogonal to its surface; hence the optimal target locations and/or saccade vectors were comparable across all recording contacts. The target was positioned either close to the center of the response field or at the diametrically opposite location. Here we looked at the spiking activity at different epochs during each trial and classified the neuron's response into visual burst movement burst and build-up neuron. Preliminary analyses reveal a 4-fold division of the SC: 1)\tNeurons presenting visual burst activity without pre-saccadic build-up activity nor movement burst activity were mostly found at the most dorsal positions. 2)\tNeurons presenting visual and movement burst activity without pre-saccadic build-up were mostly found deeper than the neurons described in 1). 3)\tNeurons presenting visual and movement burst activity with a pre-saccadic build-up of activity were mostly found deeper than the neurons described in 2). 4)\tNeurons presenting movement burst activity without pre-saccadic build-up activity were mostly found deeper than the neurons described in 3) and at the most ventral positions. Taken together these results may suggest the existence of a laminar organization of the spiking activity in SC. What makes this functional organization a suited neural network architecture for realizing the sensorimotor transformation will be the object of future research.

First Author: Michael Granovetter (Graduate)	Poster Session: am
Presenting Author: Michael Granovetter (Graduate)	Location: 52
Mentor/Lab: Marlene Behrmann	Category: Brain Models and Systems
Department: Medical Scientist Training (MD-PhD) Program	

Title: Atypical task-evoked pupillary responses in individuals with autism implicate norepinephrine's contributions to imbalances in neural excitation and inhibition

Summary: We measured pupil dilations (an established approach to infer the amount of norepinephrine produced in the brain) as participants with and without autism performed a working memory task. Our preliminary analyses suggest that individuals with autism produce higher levels of norepinephrine in the brain compared to neurotypical controls.

Abstract: An imbalance in excitatory and inhibitory neural activity is postulated to be associated with features of autism spectrum disorders although the neurobiological mechanisms underlying such an imbalance remain unclear. Norepinephrine (NE) produced from the locus coeruleus (LC) globally regulates the homeostasis of neural excitation and inhibition by enhancing the signal-to-noise ratio or neural gain of circuits throughout cortex. We hypothesize that individuals with autism exhibit an imbalance in excitatory and inhibitory neural activity as a consequence of atypically elevated release of NE from the LC. To test this hypothesis we measured pupil size (an established correlate of LC activity and cortical NE production) in 15 individuals with autism and 13 age-matched neurotypical controls as they performed a one-back working memory detection task. Our preliminary analyses suggest that while both groups performed the task with similar proficiency individuals with autism exhibited lower task-evoked pupil dilations compared to controls. As the magnitude of the pupil dilation is inversely correlated with tonic cortical NE release from the LC our data suggest that individuals with autism generate higher concentrations of tonic NE relative to neurotypical individuals. Given the critical role of the LC in attention and learning an inherent difference in cortical NE production in individuals with autism could potentially contribute to cognitive deficits observed in ASD and thus warrants further study.

First Author: Jesse Wood (Postdoctoral)	Poster Session: am
Presenting Author: Jesse Wood (Postdoctoral)	Location: 53
Mentor/Lab: Ahmari	Category: Brain Models and Systems
Department: Psychiatry	

Title: Stimulation of medial orbitofrontal cortex terminals in ventromedial striatum causes neuroplastic changes in cortex

Summary: Stimulating cortical neuron terminals in striatum causes plasticity in cortical networks

Abstract: Optogenetic stimulation of specific neuronal projections is a powerful tool for dissecting neural circuit function but the network effects of axon terminal stimulation have not been thoroughly explored. To study these effects we optogenetically stimulated medial orbitofrontal cortex (mOFC) projections in ventromedial striatum (VMS) while recording electrophysiological activity in mOFC networks during 10 days of repeated ChR2 stimulation. We observed that stimulation of terminals in VMS caused highly entrained population spikes in mOFC; single unit spikes rarely occurred during the inter stimulus interval (i.e. between light pulses). To facilitate identification of population spikes we developed a novel optogenetic stimulation paradigm To investigate the chronic effects of this synchronous entrainment we measured pairwise cross correlations between mOFC neurons in 15-minute periods preceding and following stimulation. Prior to stimulation in session 1 there was no mOFC synchrony in ChR2 animals (0/66 pairs of simultaneously recorded mOFC neurons). Immediately following stimulation in the first session synchrony between mOFC neuron pairs had begun emerging. Synchrony grew more prominent in sessions 5 and 10 in mOFC networks in association with repeated optogenetic stimulation. In contrast significant pairwise synchrony was extremely rare in control mice. These data demonstrate that terminal stimulation of corticostriatal projections causes antidromic activation and entrainment of mOFC and that this activation induces neuroplastic changes in mOFC networks. These findings have broad implications for the effects of terminal stimulation on corticostriatal networks. The dissolution of distributed single unit spiking suggests that entrainment of recorded neurons was highly uniform and potentially spread to non-VMS projecting neurons. Furthermore because increased cortical synchrony is reflective of increased shared connections between neurons these data raise the possibility that antidromic activation of corticostriatal projections induces a long-lasting change in connectivity within the cortex. Taken together these findings provide evidence for a novel mechanism through which optogenetic stimulation of specific projections can alter circuit activity and plasticity in a broader manner than previously suspected.

First Author: Caroline Runyan (Faculty)	Poster Session: am
Presenting Author: Caroline Runyan (Faculty)	Location: 54
Mentor/Lab: Caroline Runyan	Category: Brain Models and Systems
Department: Neuroscience	

Title: Communication between cortical networks: context inhibition and neuromodulation in cells and circuits

Summary: The meaning of a sensory stimulus can change depending on the current situation and the ability to flexibly and appropriately adjust behavioral responses in changing contexts is critical for survival. The goal of my research is to understand the circuit mechanisms that control the flow of information between brain regions.

Abstract: The brain is often bombarded by information from multiple sources simultaneously and rapidly changing contexts can shift the behavioral relevance or meaning of a sensory stimulus requiring an animal to respond to the same stimulus differently depending on the current situation. The ability to flexibly and appropriately adjust behavioral responses in changing contexts is critical for survival and disruptions in this flexibility characterize many complex brain disorders such as addiction autism and schizophrenia. The goal of my research is to dissect the circuit-level mechanisms underpinning cognitive and behavioral flexibility to enable new systems-level approaches to understanding these disorders in the near future. To understand the neural underpinnings of perception attention and behavioral flexibility it is critical to study the interaction between brain areas as even regions of primary sensory cortex do not operate on feedforward inputs in isolation. Each local patch of cortex in sensory and association regions receives feedforward lateral and feedback inputs. We will use optogenetics and two-photon imaging of calcium responses in genetically defined cell classes to dissect the local circuit mechanisms controlling the efficacy of signal transmission between cortical regions with different hierarchical relationships in changing behavioral contexts.

First Author: Arish Alreja
(Graduate)

Poster Session: am

Presenting Author: Arish Alreja
(Graduate)

Location: 55

Mentor/Lab: Christopher J. Rozell (Georgia Tech - Sensory Information Processing Lab) Ilya Nemenman (Emory University - Department of Biology)

Category: Brain Models and Systems

Department: Electrical Engineering (Georgia Tech) Biology (Emory University)

Title: Optimal E:I cell ratios in efficient coding models of V1 under volume constraints

Summary: Two different classes of neurons (those which excite other neurons and those which inhibit) are found in the brain. They account for different fractions of the neural population in different species (10-25% Inhibitory Neurons). The computational role of each type of neuron and factors governing this proportion remain an open question. In this work we use a biologically plausible model of vision and place it under a neural constraint (size of the neural population) to understand the computational principles that govern the balance between Excitatory and Inhibitory Neuron sub-populations in cortex.

Abstract: The inhibitory interneuron population plays an important role in shaping cortical activity but much remains unclear about its specific role in neural coding. While some theoretical models postulate the need for balanced excitatory and inhibitory activity we lack an understanding of why cortical E:I cell ratios in different species are consistently in a range from 2:1 - 9:1. Understanding the principles underlying E:I ratios may help illuminate the role of inhibition in cortical circuits. Recent efficient coding models of vision include explicit inhibitory interneurons with biologically observed E:I ratios and interneuron tuning properties. While similar models show that increasing the number of excitatory and inhibitory cells improves the quality of stimulus representation current models do not account for the fact that volume is a heavily constrained resource. Though both excitatory and inhibitory cell types are valuable for neural coding a fixed volume constraint means that increasing the size of one neural subpopulation necessitates decreasing the size of the other. We implement an efficient coding model of vision under a volume constraint that fixes the total population size while varying the E:I ratio. We show that the quality of the stimulus representation is optimal at biologically observed E:I ratios which can be interpreted as balancing the trade-off between computational accuracy and representation capacity for natural stimuli. This potentially provides a normative account for observed cell type distributions in sensory cortex as optimizing coding fidelity under a volume constraint. Further our model suggests that specific optimal E:I ratios within biophysically observed ranges are proportional to population sparsity with higher optimal E:I ratios observed for sparser population activity. This prediction is supported by recent electrophysiology recordings of large populations in V1 under natural scene stimuli for multiple species.

First Author: Man Wu (Graduate)	Poster Session: am
Presenting Author: Man Wu (Graduate)	Location: 56
Mentor/Lab: Stephen D. Meriney	Category: Brain Models and Systems
Department: department of neuroscience	

Title: GV-58 a novel calcium channel gating modifier reverses aging-induced weakness in transmitter release from mouse neuromuscular synapses.

Summary: GV-58 could be developed as a symptomatic treatment for neuromuscular weakness associated with aging.

Abstract: We have studied the changes in neuromuscular junction (NMJ) structure and function as these synapses mature and undergo age-related changes. Our goal was to test the hypothesis that our newly developed calcium channel agonist gating modifier (GV-58) could provide symptomatic relief for normal aging-related NMJ weakness. First we documented changes in NMJ organization and function with aging. Neuromuscular synapses matured to their adult form and function over the first few months after birth and then remained relatively stable at a quantal content of about 80 for about 14-16 months. The first aging-related changes appeared to be postsynaptic as receptor staining broke apart (documented by small patches of α-bungarotoxin staining) and acetylcholine sensitivity appeared to be reduced (as evidenced by reductions in miniature endplate potential amplitude). These postsynaptic changes began at about 17-18 months of age and progressed gradually until death (between 24-32 months of age). The hypothesized reduction in postsynaptic acetylcholine receptor sensitivity was supported by what appeared to be a presynaptic homeostatic increase in transmitter release between 18-24 months of age (quantal content averaged 131.6 + 10.4 at 20 months of age). This transient increase in quantal content reversed and transmitter release was reduced such that by 25-30 months of age quantal content was significantly lower than normal adult values. This age-related biphasic time-course of changes in presynaptic quantal content gradually led to NMJs with reduced immunohistochemical staining for presynaptic markers of active zone organization (bassoon and Cav2.1 calcium channels). Interestingly after NMJs became weaker than normal adults (quantal content averaged 23.0 ± 3.6) and before they degenerated to the point that transmitter release was nearly eliminated (endplate potentials less than 2 mV) our novel calcium channel agonist gating modifier (that prolongs mean open time) could reverse synaptic weakness (increasing quantal content to an average of 45.7 ± 6.5; or a paired analysis increase of 2.35 ± 0.3 fold). These data provide evidence that GV-58 could be developed as a symptomatic treatment for neuromuscular weakness associated with aging.

First Author: Finnegan Calabro (Faculty)	Poster Session: am
Presenting Author: Finnegan Calabro (Faculty)	Location: 57
Mentor/Lab: Laboratory of Neurocognitive Development	Category: Learning
Department: Psychiatry and Bioengineering	

Title: Dynamic changes in striatal dopamine predict reward learning: evidence from simultaneous PET/MR

Summary: We have used simultaneously acquired fMRI and PET imaging to assess the relationship of dopaminergic brain activity with reward learning. We found differences in both activation and dopamine release associated with the ability of subject to learn based on reward-feedback. This provides direct in vivo support for the role of striatal dopamine not only in responding to rewards but in using them as the basis for learning.

Abstract: Dopamine is strongly associated with reward processing in the striatum but its precise contribution to reward learning in humans has been difficult to characterize. Here we combined behavioral (reinforcement learning) modeling with simultaneously acquired task fMRI and PET to assess the relationship of dopamine signaling and brain activation to reward related behavior. A sample of 77 young adults (40 female ages 18-30) were scanned in a Biograph MMR combined PET/MR scanner during which subjects performed a rewarded map exploration task in which they attempted to accumulate rewards and learn reward probabilities for each map location. Performance data was characterized using a reinforcement learning (RL) model to assess learning parameters. A bolus/infusion paradigm was used to administer the D2/D3 ligand [11C]Raclopride and task-related DA was quantified as a change in binding potential (BP) using a modified version of the simplified reference tissue model (SRTM). Task fMRI data was acquired simultaneously and activation was assessed by comparing BOLD responses among high low and no reward trials. Voxelwise analysis of the PET data across the striatum showed significant decreases in BP during task in bilateral portions of the ventral striatum (nucleus accumbens NAcc) and dorsal putamen indicating task-related DA release. Notably the magnitude of DA release was greater among subjects who exhibited reward learning compared to non-learners in the NAcc but not putamen. Furthermore among learners DA release in the NAcc was positively correlated with learning rate. DA responses were highly correlated with BOLD reward responses in the NAcc and this effect was more closely related to parametric prediction error related activation than to reward expectation. Non-learners did not show any relationship between DA and BOLD. Our results provide direct in vivo support for dopamine signaling in NAcc contributing to the neural and behavioral indices of reward learning. These data confirm and extend models of reward-related dopamine signaling from rodent and primate studies.

First Author: Amy Ni (Postdoctoral)	Poster Session: am
Presenting Author: Amy Ni (Postdoctoral)	Location: 58
Mentor/Lab: Marlene Cohen	Category: Learning
Department: Neuroscience	

Title: Neuronal population changes underlying visual perceptual learning and attention

Summary: Attention and perceptual learning can both improve perception on the same visual task. However they operate on very different timescales. We found a single robust relationship between changes in neuronal activity and changes in behavioral performance whether those changes occurred quickly with attention or slowly with perceptual learning.

Abstract: Understanding the way that different processes that improve perception affect populations of neurons might help identify the aspects of the neural code responsible for perception and cognition and test the hypothesis that a single neuronal computation underlies all processes that improve perception. We compared the neuronal correlates of attention which improves perception of important parts of a crowded scene to those of perceptual learning which slowly improves observers' ability to discriminate well-practiced stimuli. While these two processes both improve perception they operate on very different timescales: attention can fluctuate on the scale of hundreds of milliseconds while perceptual learning improves performance over weeks to months of repeated practice. We recorded from populations of neurons in V4 using multi-electrode arrays while two rhesus monkeys learned to perform a visually guided task that required that they switch attention between two visual stimuli. This approach allowed us to simultaneously measure the effects of attention and perceptual learning on perception and on populations of visual neurons. Both attention and perceptual learning improved perceptual performance and both affected the extent to which trial-to-trial variability in response to repeated presentations of the same stimulus was correlated between pairs of neurons. Further we found a single robust relationship between correlated variability and behavioral performance whether correlated variability changed quickly with attention or slowly with perceptual learning. Finally we found that correlated variability was oriented along the dimensions in population space used by the animal on a trial-by-trial basis to make decisions. These findings support the hypothesis that all processes that improve perception use similar neuronal computations.

First Author: Judy Cameron (Faculty)	Poster Session: am
Presenting Author: Samantha Sostorecz (Graduate)	Location: 59
Mentor/Lab: Working for Kids: Building Skills	Category: Learning
Department: Neuroscience and Psychiatry	

Title: Evaluation of the Effectiveness of a New Neuroscience Education Program to Inform Communities about How to Improve Children's Brain Development

Summary: Working for Kids: Building Skills (WFK) a neuroscience outreach program is designed to teach the general public about healthy childhood brain development in a fun and interactive way. In six hour periods WFK trained professionals who work with children and pre-professional college students on the importance of strengthening children's brain pathways. We found that there is no significant difference between how well the material is learned between the two groups suggesting WFK is very effective in teaching nonscientists the basics of developmental neuroscience and that the material is equally accessible to pre-professional students.

Abstract: Children who have faced significant early life stresses are at a much higher risk of not reaching their maximal potential in terms of education physical health mental health and economic success in the workplace. Increasing the availability of supportive and enriching experiences can improve children's outcomes but in stressed communities there is often little knowledge of how to help children strengthen the many brain pathways they need for successful life skills. The Working for Kids: Building Skills™ (WFK) educational platform was designed based on principles of developmental neuroscience to educate the general public about how to strengthen children's brain pathways for a diversity of cognitive skills and social-emotional skills. The educational tools are fun easy to use and designed to be useful for those with a variety of educational and cultural backgrounds. Topics covered explain how experiences shape brain development the importance of supportive environments and the value of community supports in counteracting the effects of early life stresses. This study was designed to assess the effectiveness of WFK in teaching professionals (social workers home visitors public health professionals) how experiences can strengthen children's brain pathways. 175 professionals received the WFK six hour educational program. Three questionnaires each comprised of 5 true/false questions were given over the course of training to evaluate how well the participants learned basic neuroscience principles. Professionals correctly answered questions 88.98 ± 3.79% 91.34 ± 5.63% and 91.1 ± 5.12% after sessions 1 2 and 3 respectively. Seventy pre-professional college students also received WFK training. Pre-professionals who only completed session 3 correctly answered questions 94.9 ± 3.88% not significantly different from the professionals who were trained. WFK also collected qualitative data asking participants what was most interesting about the program and what they would change. 51.2% enjoyed learning about brain development and 31.3% enjoyed the Brain Architecture Game an active learning game showing the impact of life experiences on brain development.17.5% enjoyed other parts of the educational program such as how the program was presented. 64.79% said they would change nothing about the educational program while others suggested covering more topics. Overall we conclude that the WFK educational program is very effective in teaching nonscientists the basics of developmental neuroscience and that the material is equally accessible to pre-professional students. It is our hope that this program will be effective and engaging enough to have widespread adoption in stressed communities. Ongoing studies are evaluating the effectiveness of the WFK train-the-trainer program in teaching non-professional adults living in these communities about how to facilitate sturdy brain development in children.

First Author: David Montez (Postdoctoral)	Poster Session: am
Presenting Author: David Montez (Postdoctoral)	Location: 60
Mentor/Lab: Beatriz Luna	Category: Learning
Department: Psychiatry	

Title: Developmental stabilization of neural gain signals improves mean behavioral performance and behavioral variability

Summary: We develop a computational model of working memory processes that accounts for developmental changes in behavioral performance observed during adolescence.

Abstract: Behavioral variability is an important barometer of cognitive functioning. During adolescent development behavioral responses both improve on average as well as stabilize. Mechanistically accounting for the stabilization of behavior is critical to our understanding of adolescent neural development. Here we report results from a longitudinal working memory study performed over 10 years in a cohort of 126 subjects between the ages of 8 and 33 years. We develop a computational model of memory-guided saccade (MGS) performance and demonstrate that improvements in mean behavioral performance and behavioral variability can be accounted for solely in terms of stabilizing neural variability. We find that behavioral performance in the memory-guided saccade task improves and stabilizes during adolescence. By incorporating multiple sources of independent gain variability in a high-dimensional drift diffusion race model that we can account for the improvements in mean behavior and behavioral variability that are observed during adolescent development. Analysis of the trial-to-trial relationship between memory-guided saccade reaction times and accuracies reveals a peculiar U-shaped speed-accuracy relationship. Further analysis shows that this relationship can be accounted for by a balance of independent variability affecting working memory and response threshold gain signals. Our results indicate that independent trial-to-trial variability in gain signals that affect working memory maintenance and response thresholds can account for peculiar speed-accuracy relationships observed in our data. Moreover developmental improvements in both mean behavioral performance and behavioral variability can both be accounted for by the parallel stabilization of two independent sources of neural gain variability.

First Author: Robert J. Ferguson (Faculty)	Poster Session: am
Presenting Author: Robert Ferguson (Faculty)	Location: 61
Mentor/Lab: Biobehavioral Oncology Program UPMC Hillman Cancer Center	Category: Learning
Department: Medicine Division of Hematology/Oncology	

Title: Cognitive-Behavioral Treatment of Cancer-Related Cognitive Dysfunction: Treatment Dissemination and Outcomes Monitoring of Survivors

Summary: Cancer-related cognitive dysfunction (CRCD) can last for years following treatment of many different forms of cancer and can have significant negative impact on employment social and family roles. Memory and Attention Adaptation Training (MAAT) is a non-drug brief behavioral treatment of CRCD that has been found to be effective in clinical research but helping professionals such as psychologists receive training so they can offer MAAT to survivors has been a challenge. We are developing and implementing an online training program for MAAT for psychologists and others (anywhere there is an internet connection) and an online system so we can monitor memory and attention function of survivors who are treated with MAAT.

Abstract: Objective. Cancer-related cognitive dysfunction (CRCD) affects roughly half of all cancer survivors and has long-term (> 10 years) significant negative effects on social vocational and emotional function. Memory and Attention Adaptation Training (MAAT) is an evidence-based cognitive-behavioral therapy (CBT) that improves survivor quality of life patient-reported and objective neurocognitive function. However disseminating CBT's to clinical use and evaluating real-world effectiveness in cancer survivors suffering CRCD remains a challenge. We describe a treatment dissemination and outcomes monitoring system that uses internet technology to train clinicians and the Patient Reported Outcomes Measurement Information System (PROMIS) to evaluate MAAT clinical outcomes. Methods. First MAAT training utilizes a web-based videoconferencing workshop with live interactive learning with licensed qualified health professionals involved in cancer care-- regionally nationally and internationally. Second we describe an outcomes monitoring system where individual survivors enrolled in MAAT will respond to PROMIS measures of daily cognitive symptoms and emotional distress through a secured web-portal. Data security data management and analysis utilizing single case designs and aggregate analyses to evaluate MAAT effectiveness is described. Results. Information gained through the PROMIS-based MAAT outcomes monitoring system will provide greater detail of MAAT “real-world” effectiveness as a treatment of CRCD. This can include survivors who have not been carefully selected for previous MAAT randomized trials such as those with medical comorbidities that affect cognitive function (e.g. vascular disease) varying cancer treatments (e.g. hormonal therapies or immunotherapies) and history of traumatic brain injury. The proposed PROMIS outcomes monitoring system can thus help identify moderator variables that influence MAAT effectiveness and identify which survivors who are most likely to benefit. Conclusions. Using web-videoconferencing and PROMIS technology may provide a realistic method of disseminating and evaluating evidence-based treatment and translate cancer survivor research into practice. This system is currently being implemented and evaluated.