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McNair Session - Improving Lives via Engineering, Neuroscience, Evolutionary Biology, and Psychology

Session Moderator: Gene Kim, Education, Office of Minority Affairs & Diversity

287 MGH

3:45 PM to 5:15 PM

* Note: Titles in order of presentation.

Circadian Modulation of Neuromotor Control

Jennifer Jane (Jennifer) Gile, Junior, Neurobiology
Mary Gates Scholar, McNair Scholar
Mentor: Horacio de la Iglesia, Biology

The circadian system controls daily rhythms of behavior and physiology, including locomotor activity and motor-task performance. The master regulation of these rhythms is achieved by a circadian clock located in the suprachiasmatic nucleus of the hypothalamus; however, it is not clear how motor tasks are programmed by the motor cortex at different times of the day. Our hypothesis is that similar motor tasks executed at different times of the day may require different motor programs to account for the daily variance introduced by the circadian system. How and where in the brain this variance in motor control manifests has not been established. We propose to identify specific primary motor cortex activity patterns associated with specific motor outputs across the 24-hour day. We implant electrocorticographic (ECoG) electrodes onto the motor cortex of mice and record brain wave activity during wheel running and rest. We first test whether the motor cortex may show a brain-wave signature for wheel running, and second whether this signature may change predictably across the 24-hour day. Initial results indicate a broad-spectrum power increase in brain-wave output from the motor cortex associated with wheel running. Furthermore, there appears to be a circadian modulation of the power of specific ECoG frequencies. The decoding of motor cortex signals is at the core of the design of brain-machine interfaces (BMIs). These devices decode signals from the conscious brain to drive the execution of specific tasks by a machine, such as an artificial limb. Our work will directly contribute to our understanding of how the motor cortex decodes circadian time. This knowledge is essential to create BMIs that can operate effectively throughout the 24-hour day to execute tasks by brain-operated artificial devices.

Perception and Physiology: A Neurobiological Perspective on Cognition and its Potential Consequences

Tabatha Memmott, Senior, Organismal Biology, Public Health Education, Portland State University
McNair Scholar
Mentor: Barry Oken, Neurology and Behavioral Neuroscience, Oregon Health & Science University

Studying human perception from the perspective of a biologist or physician is a recent innovation, whose aims were previously appropriated by the domain of psychology. Yet in recent years, emphasis on perception has grown in fields like psychosomatic medicine, behavioral neuroscience, stress physiology, and complementary/alternative medicine. This new perspective on perception has prevailed with increased rates of psychosomatic disorders that have physiological and cognitive components (Post Traumatic Stress Disorder (PTSD), depression, etc.), and through recent technological advances made available to researchers (EEG, fMRI, etc.) Most specifically, technological innovations have enabled less invasive and more precise studies of neuroanatomy, which enables us to connect precise physiology with corresponding cognitive change. The manner in which a stimulus is perceived, and the resulting trauma, reward, danger or stress, then cognitively processed can have positive or negative physiological outcomes for individuals. However, researchers are just beginning to understand this mechanism and its implications.My research will study activation differences during visual working memory (VWM) tasks in stressed individuals. The ability to hold and process information in the VWM is related to general alertness, and I anticipate finding that stress will impair functionality of the VWM. This can be ascertained using electrophysiology (event-related potentials). These results would help establish the cycles or mechanisms that characterize these disorders and produce their cognitive-processing malfunctions. I hope

to increase awareness of the genuine and detrimental progressions of these disorders, while also identifying treatments that effectively ameliorate both symptoms and identifiable lesions (chemical, physical, or otherwise). Understanding these pathways can assist in the recovery from disorders such as PTSD and depression, or potentially shorten a patient's stay in hospital, where serious infection rates and stress are high, and overall comfort, low.

A New Approach to Controlling Epilepsy through p38 MAPK

Vicky Herrera, Senior, Biochemistry
Amgen Scholar, McNair Scholar, Undergraduate Research Conference Travel Awardee
Mentor: Nicholas Poolos, Neurology

Epilepsy is a neurological disease characterized by recurring seizures and it affects millions. We hypothesize that modulation of p38 mitogen-activated protein kinase (p38 MAPK) will influence hyperpolarization-activated cyclic nucleotide-gated (HCN) channel activity, affecting the frequency of seizures in an animal model of epilepsy. p38 MAPK is a kinase activated by conditions of cellular stress. It strongly stimulates the HCN channels, which are voltage gated ion channels that are highly expressed in the cortex and hippocampus, brain regions where seizure onset occurs. A decrease in HCN channel expression or function has previously been observed in epileptic animals associated with a loss of p38 MAPK activity, which produced neuronal hyperexcitability. We hypothesized that increasing p38 MAPK activity might decrease neuronal activity and decrease seizure frequency. In this experiment, Epilepsy was induced in Sprague Dawley rats through treatment with pilocarpine, a convulsant drug. Recurrent, unprovoked seizures were seen after three weeks of treatment. An osmotic pump was placed in the rats, delivering drugs that modulate p38 MAPK. The drug SB203580 (SB), a specific inhibitor of p38 MAPK, was administered, as was anisomycin, a non-specific activator of p38 MAPK. Animal brain activity was analyzed with video electroencephalography through electrode implants in the skulls of the rats. Inhibition of p38 MAPK by SB increased seizure frequency by 179 % as predicted, however, anisomycin also increased seizures by 236%. We hypothesize that this may be due to non-specific actions on other signaling pathways like the Jun N-terminal kinase pathway (JNK). We're investigating the role of JNK in modulating seizure frequency, and this may point us to some new therapies. The implications of this study may indicate a new approach to the control of epilepsy via anti-epileptic drugs targeting p38 MAPK.

The Evolution of Incipient Cooperation: Pleiotropy as a Mechanism to Promote Cooperation

Jose Mario Bello (Jose) Pineda, Senior, Neurobiology, Mathematics
EIP Scholar, Mary Gates Scholar, Presidential Scholar
Mentor: Wenying Shou, Basic Sciences, Fred Hutchinson Cancer Research Center

Cooperative interactions are observed at all levels of biological organization. Genes cooperate to form genomes, bacteria aggregate to form biofilms, and individuals organize into societies. The formation of cooperation facilitates the transition from simple forms of life into higher levels of biological complexity. In these systems a cooperator enhances the fitness of its partner at its own expense. Yet Darwinian evolution favors selfish acts which promote individual fitness, rather than selfless acts which incur a cost to the altruist. How could cooperation evolve under this paradigm which, seemingly, is its antithesis? To address this question, I have used a synthetic cooperative system, amenable to genetic and quantitative analysis, termed CoSMO (Cooperation that is Synthetic and Mutually Obligatory), as a model for incipient cooperation. CoSMO is an engineered system consisting of two reproductively isolated *Saccharomyces cerevisiae* strains: a red-fluorescent strain that overproduces adenine but requires lysine, and a green-fluorescent strain that overproduces lysine but requires adenine. Evolved CoSMO cocultures are able to survive significant reductions in population density. We have determined that adaptations in the lysine-requiring, adenine-overproducing cooperator are sufficient for this system level improvement. Phenotypic analyses revealed that evolved CoSMO cooperators exhibit increased tolerance to limited lysine, and increased adenine release. These evolved phenotypes are attributed to mutations in *ECM21* and *RSP5*, genes controlling ubiquitin-mediated endocytosis of membrane transporters. These mutations facilitated adaptation to nutrient limitation by stabilizing the high-affinity lysine transporter *LYP1* on the plasma membrane. Simultaneously, they increased adenine release to the partner via membrane stabilization of the purine-cytosine permease *FCY2*. Thus, pleiotropy, the influence of one gene over multiple phenotypes, can serve as a mechanism to stabilize incipient cooperation. Through mutations in pleiotropic genes, genetically optimizing self-interest during the cooperative interaction still allowed individuals to directly benefit their partner, thus allowing cooperation to persist under Darwinian selection.

Origami Based Sustainable Packaging Design

Alma Emadi, Senior, Industrial Engineering, Mathematics
EIP Scholar, McNair Scholar
Mentor: Magnus Feil, School of Art/Division of Design

Packaging and the products associated with it produce millions of tons of waste every year - over 70 million tons in

the U.S. alone in 2009. About 40% of this waste is recycled or reused, but the other 60% winds up in the landfill. According to the EPA, reducing packaging waste by only 25% would reduce carbon dioxide emissions by 20-50 million metric tons ($MMTCO_2$) per year. This among many other benefits is equal to reducing the environmental harms of 216,000 passenger cars not driven for one year. This study investigated sustainable packaging solutions dervied from traditional origami designs and asks the questions: can these designs reduce environmental waste and is origami design widely feasible based on current market needs for reliability of packaging and associated costs? To do this, I designed an origami-based packaging solution for emergency aid packages containing food, water and survival supplies. I used the resulting design to assess at the product's life cycle, affectability and its aftermath. What happens to a product after its life is just as important a design consideration as its lifetime requirements and attributes. The results of this research show that sustainability does not have to expensive and complicated. Rather it can be achieved through simple design and creative considerations.