IGERT Integrative Graduate Education and Research Traineeship

Neuroengineering: From Cells to Systems

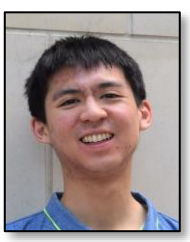
PI: Robert M. Raphael, PhD, Bioengineering, Rice University

neuroigert.rice.edu

Currently Appointed IGERT Trainees
Fall 2017

Krishna Badhiwala
Bioengineering, Rice University
Mentor: Jacob Robinson, PhD
Title: Scalable Microdevices for Neuroscience with Small Organisms
Small organisms such as Hydra provide a useful model for studying the nervous system. These transparent invertebrates can be manipulated in microfluidic chambers to image almost every neuron. Neuronal calcium imaging combined with electrophysiology provide the resolution needed to identify single action potential events and the individual neurons associated with observed animal behavior. This project aims to study the neural processes underlying animal behavior using small model organisms in a microfluidic platform.

Madeline Burns
BioSciences, Rice University
Mentor: Julia Saltz, PhD
Title: Individual Differences in Decision Making and Learning
Understanding how and why individuals differ in learning is important, both for generating predictive models of how previous experience may impact future decision making, as well as informing how neurological therapies may be tailored to the individual. My project focuses on how critical early stages of learning (such as differences in how individuals encounter, perceive, and respond to stimuli in their environment) contribute to variation. Comparing two different species (Drosophila simulans and D. sechellia), I am investigating how differences in willingness to explore a novel environment and strength of preference influence learning ability. This study will provide novel insight into how factors such as personality and preference influence the learning process to generate consistent individual variation.

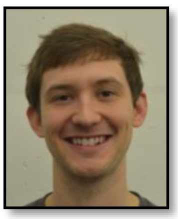


Joshua Chu
Electrical & Computer Engineering, Rice University
Mentor: Caleb Kemere, PhD
Title: Probing Mechanisms of Working Memory and Decision Making Through Manipulation of Hippocampal Circuits
My research will investigate the incorporation of information from hippocampal replay into working memory and decision making. Real time decoding of replay events and content-based perturbation of associated sharp wave ripples (SWRs) will help deepen our understanding of the contribution of replay to learning and memory processes. This study may have translational impact by revealing strategies for treatment of depression or posttraumatic stress disorder via selective replay suppressions that do not interfere with recall of other memories.

Hamin Jeon
Bioengineering, Rice University
Mentor: Tomasz Tkaczyk, PhD
Title: Minimally Invasive High Resolution Imaging of Auditory Neurons Inside a Living Cochlea
I propose to develop a minimally invasive cochlear-imaging device, based on the fast Image

Mapping Spectrometer (IMS). Overall, the proposed research plan will involve development of innovative tool that can shed more light onto the elaborate workings of hair cells and auditory neurons in cochlea and, ultimately, the mechanisms of sound transduction. This may lead to the development of new treatments for hearing loss, or improvement of existing treatment technologies such as cochlear implant.

Colin Noe
Psychology, Rice U
Mentor: Simon Fischer-Baum, PhD
Title: Analyzing Human Speech Perception with EEG
I use EEG to study the neural and cognitive mechanisms underpinning speech perception in humans. Specifically, in our lab, we study an early EEG waveform, the N1, to index the process of phonemic perception (how parts of word sounds are identified). By measuring speech perception with EEG, we can index the various attributes of the neural representation of speech in real time. This allows us to explore cognitive questions such as: Are the processes indexed by the N1 speech specific or are they shared with other auditory domains? Does top-down information influence phonemic judgments as those judgments are occurring (and thus alter the N1 in some detectable way), or does top-down information get integrated after the N1-processes have occurred? Our exploration of these questions integrates classic ERP approaches and novel machine learning techniques to decode which types of information are available in the N1 waveform.



Matthew Evan Pezent
Mechanical Engineering, Rice U
Mentor: Marcia O'Malley, PhD
Title: Design and Control of a Robotic Exoskeletal Device for Hand-Wrist Rehabilitation
Robot-augmented therapy is a clinically verified path forward to improving rehabilitation outcomes for several neuromuscular conditions, such as stroke and spinal cord injuries. Robotic rehabilitative devices enable the high intensity, long duration interventions needed for regaining motor function, and quantitative metrics for tracking therapeutic outcomes. I am developing a combined hand-wrist robotic exoskeleton to research passive dynamics in the hand and wrist during grasping and manipulation, and then mimic such properties in collaboration with stroke rehabilitation clinicians.

Ankit Raghuram
Electrical and Computer Engineering, Rice University
Mentor: Ashok Veeraraghavan, PhD
Title: A computational framework for categorizing the depth limit of bioluminescent sources in scattering media.Bioluminescence has recently been considered as a modality to image through scattering brain tissue because of its high signal-to-noise ratio as compared to other imaging techniques like fluorescence. I am creating a framework to compute the resolution and depth limit of bioluminescence in scattering media by modeling photon trajectories using a Monte Carlo simulation as a means of estimating whether it is possible to resolve bioluminescent sources at common imaging depths for scattering media. Future work will focus on using this framework to test different parameters of bioluminescence like emission rate and different distributions of background. Knowing these limits of bioluminescence will give scientists designing bioluminescent molecules a goal to strive towards in order to image groups of neurons at particular depths.

Dan Sazer
Bioengineering, Rice University
Mentor: Jordan Miller, PhD
Title: Spatially Controlled Photo-Patterning of Multi-Material Sensory Organ Mimics
The histological architectures of mammalian sensory organs are complex and heterogeneous. Integration of discrete cellular layers allows these tissue systems to reliably sense and relay environmental stimuli, but there does not currently exist a fabrication platform that is capable of recapitulating and probing these heterogeneous organs in vitro. The central objective of this study is to use projection stereolithography (PSL) to pattern multi-material, cell-laden hydrogel constructs that mimic the heterogeneous organization of sensory tissue systems such as the retina and cochlear stria vascularis. I am developing a novel 3D printer

that implements PSL for cyto-compatible, multi-material integration, and with this system I intend to fabricate sensory organ mimics for various functional and pathological assays.

Sudha Yellapantula
Electrical & Computer Engineering, Rice U
Mentor: Behnaam Aazhang, PhD
Title: Analyzing human brain dynamics during language tasks from ECoG data, using information theoretic tools and graph theory

The human brain is a highly interconnected set of neuronal pathways, and the overarching goal of this project is to analyze macroscopic brain network dynamics during language tasks, from ECoG recordings. Information theoretic connectivity metrics like mutual information in frequency, and directed information are used to infer dependencies and information flow between brain regions. To make holistic inferences at a macroscopic scale, graph theoretic tools are used to combine network information from multiple frequency bands across time, to reveal novel patterns and shed more light on the functional connectivity patterns in the human brain during a specific language task.

Joseph Young
Electrical & Computer Engineering, Rice U
Mentor: Behnaam Aazhang, PhD
Title: Discovering the Neurophysiology of Visual Skill Learning

Despite numerous years of research on skill learning, incredibly little is understood about the neuronal explanation for why skills develop with practice. Initial research focused on single neuronal changes and yielded minimal insight. In order to truly address this question, I am analyzing neuronal interactions at the network level using recordings from rhesus macaques learning a visual task and developing data-driven approaches for such analysis. This involves the use of probabilistic metrics from information theory that can capture nonlinear interactions, such as mutual information, both in time and frequency. These tools will allow me to develop insight into the neurophysiological changes accompanying and underlying learning without imposing models.

James Webb
Neurology, BCM
Mentor: Caleb Kemere, PhD
Title: Deep Reinforcement Learning Models of Spatial Representation and Memory in Animals

Deep reinforcement learning has led to drastic technological advances in recent years, but understanding how artificial systems learn and perform tasks often remains elusive. Similarly, while neural activity in the hippocampus and adjacent structures has been well-documented, including the presence of place cells and grid cells, many questions remain about the roles of specific structures. Combining these deeply linked fields, this project aims to build neurally-inspired artificial neural networks that can perform visuospatial tasks. We wish to improve performance by modeling biological networks, which, in turn, may provide insight into the mechanisms of their underlying circuitry.

The IGERT program is Administered by the:

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Questions: Contact Vanessa Herrera
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The GCC is a collaboration of:
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