Neuroinformatics:
Using Computers to Model the Brain

Jeffrey Johnson, PhD

Computational neuroscience increases our understanding of the most complex and vital part of the body—the brain. By using computers to mathematically model biology, scientists can save human and animal lives and greatly improve clinical treatments for conditions such as Parkinson’s, Huntington’s, and schizophrenia. Dr. Jeff Johnson and colleagues are working to improve our understanding of the brain in both humans and animals, by creating computational models of 1.) animal learning and behavior and 2.) Parkinson’s disease.

Computational Models of Whole Animal Learning and Behavior

To test fear responses in animals, Johnson and colleagues created a computational model of learned avoidance behavior. In their experiment, the researchers found that if animals continue to perceive the same fear in continuing trials, their avoidance response does not stop, but rather, continues with a reduced delay time.

Similarly, in a simulated maze experiment, Johnson and colleagues created a computational model that exhibits many characteristics of animal learning in maze environments such as delay conditioning, secondary conditioning, and backward chaining. They then mapped this model to the basal ganglia to demonstrate that a learning signal in their model has the same temporal properties of dopamine, the neurotransmitter believed to play an important role in learning decision sequences.

High-Resolution Measures of Whole Animal Behavior

Currently, two-thirds of U.S. adults are overweight, and consuming a high-fat diet greatly increases the risk of obesity. Therefore, Johnson and colleagues are conducting experiments to better understand the biological and behavioral components that cause people to choose foods high in fat. In one rat study, the researchers discovered that eating a high-fat diet over a long period of time alters meal patterns and body composition. In another study, Johnson and colleagues studied the effects of the hypothalamic melanocortin system on fat intake. After injecting rats with an appetite-stimulating neuropeptide, rats chose to consume more calories from fat and fewer from carbohydrates, compared to their wild-type counterparts.
**Models of Dorsal Lateral Medium Spiny Neurons**

Using NEURON, a computer software, Dr. Johnson is working to create models of neural networks for simulation. Recently, he focused on medium spiny neurons (MSN) in the basal ganglia that are involved in motor tasks, learning, planning, cognitive function, addiction, and diseases such as Parkinson’s and Huntington’s. To test how certain neurotransmitters excite MSN, Johnson and colleagues created a biophysical model of medium spiny neurons in the dorsal lateral striatum. This model was a necessary step in achieving their research goal: to model the basal ganglia at a systems level using a network of biophysical models.

**More about Dr. Johnson**

Johnson, an Associate Professor and Director of Undergraduate Studies in Biomedical Engineering, received his PhD from the University of Cincinnati in Electrical and Computer Engineering and has worked as a research engineer for the United States Air Force. He uses his training in computer and electrical engineering in his teaching and research, focusing on computational models of learning and behavior. Dr. Johnson also serves as the faculty advisor for the student chapter of the Biomedical Engineering Society and a co-faculty advisor for the student chapter of the National Society of Black Engineers. He has served on review committees for the National Science Foundation and the National Institutes of Health.

**Research Areas**

- Computational models of animal learning and behavior
- Computational models of Parkinson’s disease

**Recent Publications**
