David St-Amand

Duke University

**Research statement**

There are three explanatory processes that underlie scientific explanation: Descriptive (what), mechanistic (how) and normative (why) explanations Neuroscience is a relatively new field, which is why most of its efforts have been focused on descriptive and mechanistic explanations. While we have learned a lot about how the brain works in the last few decades, normative explanations in neuroscience are much less developed. We currently have few neuroscience theories that make concrete predictions of how systems are wired and process information. When successful, such theories should unify experimental findings under sets of fundamental principles that explain what computations neurons perform. . My goal as a researcher is to bridge that gap by developing theories that offer principled explanations for unifying phenomena in neuroscience. To that end, I am currently doing theoretical work on the retina under the supervision of John Pearson at Duke University. My long-term goal is to become a professor in theoretical neuroscience at a top University like Duke. I personally believe that it is only a matter of time before we develop general theories that explain how the brain functions, and I would love to dedicate my career to help push theoretical neuroscience to develop such unifying principles.

The early visual system is one of the neural systems best understood, making it a great foundation for building normative explanations of how neural systems function. This became apparent to me at the end of my undergraduate studies, which is why I chose to research visual neuroscience under the supervision of Dr. Curtis Baker for my Master’s at McGill University. In that work, modeled responses of the primary visual cortex to natural images using machine learning. We showed that primary visual cortex neurons have weaker inhibition to dark than light stimuli in their early, but not late, responses. This research resulted in a first-author paper entitled **“Model-based approach shows ON pathway afferents elicit a transient decrease of V1 responses”** in the Journal of Neuroscience. My Master’s granted me a solid understanding of what we know about how the early visual system is wired. I would next like to use my knowledge in visual neuroscience for theoretical work. , which I now want to use for theoretical work.

To start my training in theoretical neuroscience I started my PhD in Neurobiology at Duke University under the supervision of John Pearson. My research focuses on efficient coding, which is one of the most successful theories in neuroscience. Using principles from information theory, efficient coding provides us with a mathematical framework to understand how neurons *should* encode information, which can then be experimentally tested against how neurons *actually* do so. Over the past 60 years, efficient coding has successfully explained many experimental findings in different sensory modalities such as vision, audition, and touch. This hypothesis has been especially successful in the system I study, the retina, where it can explain many features of encoding such as center-surround receptive fields and ON-OFF pathways. However, we still lack efficient coding predictions for how the retina processes many complex features of the visual world such as color. More specifically, we don’t know why most retinal ganglion cells (RGCs) in the fovea (the center of the retina) are midget cells, which process the difference between red and green stimuli. My work will tackle this problem by providing a theoretical account of how the retina integrates redundant inputs across different color channels. We will do so by building an efficient coding model that optimizes the mutual information between natural images and model RGC responses. My lab has previously been successful at building such models, which were used to explain why ON-OFF mosaics in the retina are anti-aligned. Completion of this project will result in testable predictions for efficient coding of motion in natural images, which we will be able to compare to experimental data from the Field Lab at UCLA. I expect this training to improve my computational skills,, and will be the first step towards my goal of building better normative explanations in neuroscience.

Computational methods are becoming more and more important in neuroscience, which is why I want to help the communities I’m in to develop their computational skills. I started doing so at my previous institution, where I taught both statistics and programming. I taught statistics by tutoring undergraduate students at McGill University for about two years. I taught programming through workshops: I hosted my own programming workshop in R for graduate students, and was a teaching assistant for a programming workshop in Python. During my PhD, I would like to keep doing the same and teach computational skills to Duke graduate students.. There are many opportunities that will allow me to do so, such as being a teaching assistant for the statistics or programming courses in Neurobiology, or teaching in the bi-weekly methods workshop for neuroscientists. These opportunities are great teaching experiences that will not only help my community but also prepare me to become a professor in the future.

After I complete my graduate training at Duke, I want to pursue a post-doc with the goal of becoming a professor in theoretical neuroscience. I want to develop theories of how the brain works that not only apply to the retina, but to the brain as a whole. I am especially interested in studying computational models of inhibition and synaptic plasticity and using such models to explain how systems (e.g., vision) process information. Combined with my current rigorous training in computational methods, my previous training in experimental neuroscience would make me the perfect candidate to collaborate with experimentalists and build theoretical models from their data. Receiving the Myra and Bonne fellowship will allow me to complete the above-mentioned research project, which I will be able to fully dedicate myself to since I will have completed my training requirements for Neurobiology next fall. Doing so will get me closer to my goal of becoming a professor in theoretical neuroscience. I hope that by developing better theories, I can help us understand the essence of what neurons do – which will, in turn, help the field to perform experiments that test and build on these ideas.