Personal, Background, and Future Goals Statement

Can we discover general principles of animal behavior and of its biological basis? Can we do so within a mathematical framework? These are some questions that excite me, keep me up at night and have long motivated me to do research. Before my family moved to the US, I used to go for walks as a child near my hometown in Brazil with my father, observing plants and animals along the way. The day I remember as the most exciting was when we found an owl nest and collected its fallen feathers: I wondered how they built their nest. My parents were incredibly supportive of my interests and education, especially considering that we come from a small town in the Brazilian countryside where education was not a priority. With their support, I soon found myself excitedly participating in mathematical competitions. My friends could not understand the reason why I would voluntarily take long and complicated tests on weekends. At that time in my life, I viewed the different sciences as being quite separate. I thought I might just be a math person, unaware that I could combine my two passions.

For years, I was the only student from my school to get accepted into the University of Sao Paulo (USP), ranked the best university in Latin America. I entered the highly competitive Molecular Sciences Program, a special core sciences curriculum where students learn about mathematics, physics, chemistry, biology and computer sciences with a research-oriented approach. Through that program, I got very interested in basic science research and realized how science can be interdisciplinary. I could now start investigating mathematical principles in animal behavior.

Intellectual merit: My research career started in my sophomore year under the guidance of Professor Fabio Tal. Due to my excellent academic record in mathematics, I was able to study advanced-level subjects related to chaotic dynamical systems. I chose that field for two main reasons: 1) the new and exciting applications of dynamical systems approaches to behavior and neuroscience; and 2) my goal towards a deeper understanding of the mathematical tools used in biology. During that summer, I pursued my interests by taking two courses at the Institute of Applied and Pure Mathematics: “Oscillations and Waves” and “Real Analysis”. Seeking more knowledge, I also completed via Coursera the course “Dynamical Modeling Methods for Systems Biology”.

By my junior year, I was ready to apply what I had learned in mathematics to neuroscience. Unfortunately, there was not an interdisciplinary lab that fit my interests at USP, so I decided to join the Timing and Cognition Lab at the Federal University of ABC in a city that was 2 hours away from Sao Paulo. I got financial support for a year from the most competitive fellowship program for undergraduates, the *Fundação de Amparo a Pesquisa do Estado de São Paulo* (FAPESP). I developed a computational model based on a sequentially activated network to understand how the brain responds during time-related tasks. I predicted the behavioral responses of rats to the peak-interval procedure, a timing task, including a central behavioral property in timing behavior, the Weber law. Through working on the project, I not only gained experience in how to apply mathematical models to behavioral data but also developed my programming skills in a variety of languages, such as Python and MATLAB. I presented my findings at two different workshops at USP (one poster and one oral presentation) and also **first-authored the peer-reviewed manuscript** “A model for the peak-interval task based on neural oscillation-delimited states” in *Behavioral Processes* (2019, Vol. 168).

When my family was granted permanent resident visas to the United States, a whole new set of opportunities became available to me. While still enrolled at USP, I earned a **highly competitive merit-based exchange scholarship from USP** - only 100 students per year are selected to receive this scholarship among the 50,000 USP undergraduate students. This provided the funds for me to move to the U.S. to pursue my dreams. I continued to participate in the Timing and Cognition Lab meetings via video conferencing and gained more independence working on my project while abroad. I increased my workload to finish all the requirements to graduate at USP by the end of my Junior year. Even with the increased workload, I kept the excellent academic standing I needed for my scholarship. For the exchange scholarship, I was accepted by Professor Asif Ghazanfar and Dr. Daniel Takahashi to join the Developmental Neuromechanics and Communication Lab at Princeton University. I started working on a project to understand the physical constraints that drive vocal development. I used open access data of vocal recordings from different species to test a stochastic dynamical model for vocal development, which I discuss in my research proposal to GRFP. Finished my first semester there, Dr. Ghazanfar funded me to on the following years to continue working on this vocal development project.

The project allowed me to develop many skills in advanced computational and statistical methods, such as in dimensionality reduction algorithms like tSNE. For each new tool that I learned, I felt that same spark of enthusiasm I had felt when studying for the mathematics competitions in high school. For my vocal development project, I presented a poster and a lightning talk during a workshop in the Princeton Center for Theoretical Science. The results of the project are promising, and we are currently preparing a manuscript to be submitted soon for publication, on which I am the first author.

Since then, I have been accepted into the Ph.D. program in Psychology at Princeton University, and in the Course on Brain, Minds & Machines (CBMM), a three-week summer workshop offered by MIT, which included full financial coverage. Over this summer period, I interacted with many scientists such as Professors Josh Tenenbaum and Josh McDermott on a project about the evolution of languages. For that project, I used neural networks to decode neural activity of human patients while watching movies and related the phonemes that were easier to decode with phonemes that are common in different languages worldwide. Despite the short time of the project, I learned about many computational methods applicable to animal behavior and neural data using *scikit-learn* or *PyTorch* and built connections with professors and other Ph.D. students that eventually might become collaborations.

Broader impacts: As soon as I started college, I recognized how lucky I was for the opportunities I had, so I decided to try my best to make these opportunities available to others. For example, in my first year at USP I applied to a project called PoliAberta. This project aimed to encourage the production of open digital classes, with not only a local impact on the university but also on a national level. Advised by Professor Antonio Carlos Seabra and Dr. Giuliano Olguin, I was involved in two major goals of the project. One goal was to help faculty with the production of open-access video lectures. This led me to produce six video lectures, including two videos about Calculus for which I was the lecturer. The other goal was aimed at understanding the current challenges in engineering outreach. For this work, I co-authored two papers that were presented in four scientific meetings including the *International Conference of Education, Research and Innovation* (ICERI) and the *World Congress on Engineering and Computer Science* (WCECS) in the United States. In one of the papers, "The impact of different production styles of videos on Online Education", we discussed how different types of video lectures (e.g. record-

ing the classroom or using digital animation) made course material more engaging. Under the supervision of my advisors, I designed and analyzed a survey involving 440 first-year Engineering students to understand the accessibility and social issues related to the use of video lectures in developing countries. We found, among other things, that there was a lack of mobile-friendly resources in the area. **This study received the Best Student Paper Award** of International Conference on Education and Information Technology 2016, earning a special publication in the journal Lecture Notes in Engineering and Computer Science (2016, Vol. 2225), entitled "Accessibility and social issues in e-Learning for engineering students". With this study, **I feel more confident in preparing material that can reach audiences from a disadvantaged background**. For example, I am now acutely aware that not everyone has equal access to internet connection 24 hours a day.

The video lectures were mostly about basic education, which is extremely important, but I wanted to contribute as well to the outreach of cutting-edge research. I continued to pursue my goal to make science more broadly available to society by helping to organize a series of open weekly seminars (CMnarios). I invited scholars from different research areas – from pure mathematics to experimental biology – to talk about their current projects and laboratory teams. This not only expanded the knowledge of the audience about different fields but also encouraged students to join laboratories to make their own discoveries.

When I moved to Princeton University, I immediately found a way to have an impact by participating in the Princeton Splash, a program that brings high school students to learn from university students. I felt fulfilled by giving classes on theoretical neuroscience and animal behavior in different editions of the program. With this program, I can have a real time assessment of how to approach certain topics, which also helps me with the creation of video lectures. I plan to produce web content about topics such as the use of mathematical tools in animal biology, with which I can quantify my impact using view counts and view demographics. If I do not get enough engagement, I will use resources from Princeton University for paid advertisement and ask for professors who already have a high impact on the community to help with sharing the content.

My research on vocal development will help advance our knowledge on communication impairments, a problem that directly prevents numerous minorities from accessing the best opportunities. The production of high-quality web content is a way to provide a feedback that might improve the viewer's communication capabilities, especially when reaching disadvantaged populations.

Future goals: I plan to continue my dynamical system research as it applies to vocal communication during my Ph.D. program. After graduating, I will pursue post-doctoral work to increase my experience and to develop and refine my own research program. I hope this will ultimately lead to a professorship. That way, I will be able to have a stronger impact on many people's education, which served as such a positive transformative experience for me. In the meantime, I will keep working with high school students through Princeton Splash and I will join both the Neuroscience Outreach program, in which we visit underprivileged high-schools to talk about neuroscience, and the Princeton ReMatch program, that encourages first and second-year undergraduates to participate in research. With support from NSF, I will be able to devote more of my time to my research and to share my knowledge with the local and national community.