Amy Shteyman Submission

Witnessing my grandparents succumb to neurological disorders turned what was a curiosity into a mission, and led me to enroll in summer neuroscience courses and start a neuroscience club. My past experiences and current research underscored how little we know about the brain's underpinnings. For two years now I have been working with a world-famous brain researcher: Dr. Joy Hirsch of Yale University. You have to understand, I want to be just like her. I picture myself as Dr. Hirsch - some would say it must be a pretty blurry picture but I'd like to think the image and the likeness are becoming more distinct and my aptitude for being a scientist is all about that picture.

First, she is a communal being. Her mentorship is often Socratic, in which direct instructions are not given, and yet at the same time she holds weekly meetings where the entire lab suggests ideas or discusses the experiments going on at that time so problems are often anticipated and solved they become major issues. Dr. Hirsch is also able to come up with clever methods to quantify things--she's got a natural feel for methodology. Finally, Dr. Hirsch homes in on projects with high levels of significance. While this in part is due to her intuition, I know that it is mostly because she reads a lot--from the ever-expanding professional literature but also stuff meant for a general audience. Her research boils down to how two brains synchronize so I wasn't surprised to see her reading *Sync*, a popular book by the mathematician Steven Strogatz on synchronized systems.

So what about me?

The research projects that I worked on prior to joining the Brain Function laboratory demonstrated a strong grasp of knowledge through reading literature. After learning about the general concept of the Goldman-Hodgkin-Katz equation in a summer course on neuroscience coming into ninth grade, I started reading a plethora of literature about how neurons function and the electro-chemical signals behind neurons. My first research project in high school was using a simulator to find ideal concentrations of ions for optimal neural functioning, and I found one level of ion concentrations fires much better than any typical levels. My ability to communicate this research allowed me to win first place in the Long Island Math Fair. With my current research project, I devised every step of it carefully and read extensively through the literature - you could also say I'm not shy at the weekly article review meetings. I started the Neuroscience Club at my school sophomore year and just like Dr. Hirsch, I implement a Socratic learning method where every member chooses a specific topic of interest, does research on that topic, and shares his/her knowledge with the club. As a Peer Leader, co-teaching a class of ninth graders on school/social/personal issues, I'd like to think I'm nurturing and bring out the best in people as Dr. Hirsch does.

It seems like I have always had a natural interest toward neuroscience, and since fifth grade I have aspired to work in a neuroscience laboratory. After having a lot of difficulty finding a neuroscience research center by sending personalized emails to professors all over the country, my teacher recommended me to the Brain Function Laboratory at Yale University under the direction of Dr. Joy Hirsch. The Brain Function Laboratory's main grant is to study the neural activity during interactions between people. Unlike many laboratories where the principal investigator or a graduate student assigns a high school student a project to do over the summer, it is Dr. Hirsch's rule that every high school student come up with his/her own project. Therefore, from the beginning of last year, I had to come up with a project that would in some way be meaningful to me and have something to do with brain activity during interpersonal interactions. It was assumed that I would be developing this project for at least two years. Around the time I had to come up with my project, the lab acquired software that precisely tracks and classifies facial expressions. Therefore, a meaningful study I could do would be to investigate the neural activity during non-verbal interactions between two people by tracking their facial expressions, specifically to investigate the brain activity of pairs of people while smiling at each other. This topic has special significance to me as well because my cousin is diagnosed with autism spectrum disorder and has a really difficult time picking up on facial cues, especially on sarcasm and humor, and I thought it would be meaningful to investigate how neural circuitry might differ when a person is smiling from another's person's smile as opposed to just seeing something else that is funny.

Putting the Grade B sci fi horror movie image of a misanthropic mad scientist feverishly working in isolation aside, there is an aspect of science that is highly humanistically social. On my first day in the lab I was terrified that the researchers would be semi-robotic monomaniacal workers who were extremely smart but otherwise indifferent to the existence of lesser mortals such as me. In reality, yes, everyone in my lab was really smart, but they were all normal, humble, interesting people with a shared desire to learn more about the brain and to help sick people. I have studied a lot of neuroscience in the past through taking summer classes, Advanced Placement Psychology, and reading Oliver Sacks books, but none of this felt as important or as personal as when I was sitting late in the lab with a post-doc, and we were trying to debug the code for my data analysis. Finally, a result came out and after weeks of problems and hardships and late nights spent at the lab, I finally felt the magic of my results coming to life. Not only was it great to finally attain results, but receiving those results with the people I have come to know so well was what made them so rewarding. Science is now a much more personal topic to me and I really understand that seemingly intuitive facts probably took a lot of ingenuity, grit, and late nights working as team to establish.

Some advice I would give to aspiring scientists and mathematicians would be to be patient, yet at the same time to be persistent with your ultimate end goal. Science probably never works out as one would expect, and while that could initially seem upsetting, the end product will be the truth of how the world works, so it is important to remain honest.

That squirrel over there has a funny looking mouth because she is stuffing too many acorns into her cheeks. It’s not a knee-slapper but it makes you want to smile. And when your neighbor takes the garbage out and smiles at you, I bet you smile back. A smile is critical in communication. A lack of smiling can be symptomatic of autism, depression, and schizophrenia. My experiment investigated the difference between brain activity while a person smiles in an interaction with another person and the brain activity while a person smiles from a non-human stimulus. Brain activity of pairs of subjects was recorded with functional near-infrared spectroscopy(fNIRS) while a facial classification device measured the strengths of their smiles. Participants alternated between viewing ‘cute’ animal videos and the face of their partner sitting across from them. Results showed even though both subjects smiled, smiling from watching a partner smile exhibited brain activity in social brain areas like Wernicke’s and Broca’s areas, and the temporal gyrus. Smiling from watching videos displayed brain activity in brain areas responsible for movement. These findings indicate that social smiles activate a separate system of brain activity that of smiles engendered by non-human stimuli.

My claim from using functional near-infrared spectroscopy (fNIRS) brain scanning is that those two smiles are neurologically different. The smile you give your neighbor after she gives one to you, the smile contagion known as the social smile, activates the Broca and Wernicke areas of the brain, as well as temporal gyrus all of which are all associated with communication and social cues. Conversely smiling because of a funny looking squirrel activates areas of the brain such as the motor and parietal cortex, which are responsible for movements and sensations. But why might it be important that there is a distinction between a social contagion smile and just a smile from a cute scene? Well it may have relevance to the neurological conditions such as major depressive disorder, schizophrenia, and autism, in which there is a lack of an ability to smile or interpret smiles. Further work would be to replicate my experiment but study the brain activity of autistics, schizophrenics, and depressive patients as they watch another person smile or as they view what most would consider to be a funny non-human stimulus. One would then compare these findings to subjects without these conditions to see whether there are differences in brain circuitry related to smiling. Once a specific neural mechanism, or barring that a specific neural region, is found to be faulty in these conditions, there could be new therapy methods and research approaches toward managing and treating these conditions.

The increasing rates of autism have been ascribed by some to a more prevalent use of refined diagnostic tools. But what if the cause of autism was environmental and ignorance of these environmental factors could magnify the effects of autism? An analogy of this situation could be that the rise in rates of autism are like the proverbial canary in a mine, warning us of severe looming neurological impacts consequent to our disruption of the environment. The big underlying question to avoid, mitigate, or possibly cure, autism is: what is the cause? First to answer this large-scale question it is critical to investigate the differences between the autistic brain and the non-autistic brain.

The most basic way of understanding autism is to see what areas of the brain light up for a given task. In quantum mechanics, the measurement of the system ends up simultaneously disturbing the system. In a way, neuroimaging in the past has worked in a similar manner. The conventional device that most studies use to investigate brain activity during tasks is fMRI. Under the best of circumstances, fMRI involves a constrained, noisy chamber, but in the worst, it could lead to anxiety and psychological distress, hardly the most amenable environment for testing autistic people.

Functional near infrared spectroscopy (fNIRS) is a minimally invasive neuroimaging device that consists of a wearable cap and optodes. This allows for the study of communication as it is possible to test human interaction in an ecologically valid environment. In my experience people with conditions such as OCD and autism only feel a slight discomfort from sitting for 40 minutes when having their brain activity studied by fNIRS.

Not only can autistic individuals feel comfortable being tested using fNIRS, but this device is specifically suited toward testing interactions between two people. fMRI was never able to test two people in a natural interaction, which fNIRS could test. A major struggle in autistic individuals from birth is interacting with other people. Multiple studies have shown that autistic individuals do not make proper eye contact while communicating, and have difficulty interpreting or producing many common facial expressions.

My study this summer tracked two non-autistic individuals interacting nonverbally, but rather through facial expressions. I showed in my study that the human brain has a mechanism specially for social interaction, and I also established the groundwork for a study on autistic interactions. If I can replicate my experiment but with autistic individuals, maybe I can show that while interacting, autistic brains have different patterns of activity during communication than non-autistic brains.

Having insight into the altered areas of brain activity responsible for facial expressions in autistic individuals could lead to a major advancement in our understanding of the neural underpinnings of autism spectrum disorder. As we begin to understand autism, we could begin to mitigate its effects and perhaps limit its occurrence within the next 20 years.