Statement of Purpose

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We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. But there are tens of thousands of years in the future. Our responsibility is to do what we can, learn what we can, improve the solutions, and pass them on.
— Richard Feynman

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1 Introduction

For many, Feynman's character is exemplary of Caltech. He was creative, honest, and more than a little eccentric. Furthermore, Feynman's genius did not prevent him from communicating science to the lay person [1]. His sense of responsibility was apparent both in the classroom as well as in the way he answered some of the biggest questions in Physics. His character demonstrates that many Caltech professors are incredibly interesting people. I respect Feynman's enthusiasm and I actively look for ways that I can pass on lessons I have learned from my mentors. Feynmann did this through his passion for teaching. From Feynman, I also realize that I am in the best position to make a contribution to society when I focus on research in which I have a sincere interest.

2 Research Interests

I was first drawn to Dr. Christof Koch's work by his approach to researching some of the most fundamental questions of human nature. I started by reading some of the articles in the news [10] [9] [17]. I thought that the ideas were exciting, but the news articles didn't make it completely clear how Christof could attempt to find a specific group of neurons responsible for consciousness awareness. Later, after reading more

technical articles [7] [8], I understood the nearer-term goal of finding *Neural Correlates of Consciousness* for specific visual percepts. *A Framework for Consciousness* clearly describes the types of mechanisms which may be responsible. For example, as illustrated by a still image which is suggestive of movement, motion may be represented by the constant firing of neurons rather than an adaption in the firing rate. I also liked the discussion on attention and binding, which may work by "biasing the competition. [7] [8]" Often, when I'm excited about a particular idea, I'll discuss it with my friends. In this case, I've become so engaged in the research at K-Lab that I've even been able to explain it to my Grandmother in a way that she finds interesting.

In addition to the *big picture*, I've looked extensively into the details of several research projects at K-Lab. My interest led me to look into the possibility of working as a volunteer at Caltech. After working out a number of difficult details, I am the first student from Kalamazoo College to undertake such a research project (off campus) during the academic senior year. I wanted to take time away from my classes in order to focus on research. This decision has already given me a greater sense of direction.

Before arriving at Caltech this term, I watched the *CNS120* lectures. I also read about perceptual suppression phenomena including motion induced blindness [6], binocular rivalry (BR) [5], and flash suppression [19] [20]. I'm interested in these phenomena because they show quite clearly that what we see is actually a reconstruction of the outside world rather than a snapshot. The first time I saw binocular rivalry, I was surprised that I could not control which image I saw. I wanted to know more about what happens to the information from the suppressed image. I imagined experiments which might imbed information in a suppressed image to further explore visual information processing. I think that psychophysical experiments are an ingenious way of doing this study and have given a number of important conclusions about where visual information is processed in the brain. Possible similarities between perception and other cognitive processes give psychophysics a greater purpose. I am also attracted to the use of fMRI—a very powerful tool for measuring brain activity.

Currently, I am working in the Koch Lab with Nao Tsuchia and Melissa Saenz. I want to know if it is possible to predict a perceptual change, from subliminal to supraliminal, by watching a buildup of activity. After preliminary psychophysical experiments, we will perform fMRI experiments involving Continuous Flash Suppression (CFS). During CFS, a different image is presented to each eye—one flashing and one stationary. Preliminary studies have shown that the stationary image can be suppressed from conscious perception (*i.e. is invisible*) for up to a minute. I'm intrigued with the way CFS builds upon several previous methods [12] [11] [15]. It allows for control of attention and expectation by using multiple suppressed images, rather than just one in BR. An advantage over flash suppression is that images can be hidden for much longer.

We can use CFS to study events occurring at the onset of conscious awareness of a stimulus. In our experiment, we will present a different image to each eye. One eye will receive continuously changing (at $10Hz$) color images of randomly placed boxes, while the other will be shown one of several suppressible images. These will include images of angry faces, neutral faces, or places.

We developed a paradigm which will allow us to observe changes in Fusiform Face Area (FFA), Superior Temporal Sulcus (STS), Amygdala, Parahippocampal Place Area (PPA), and Lateral Occipital Complex (LOC) during CFS. FFA is a cortical area responsive to images of faces, which couples with perception [15]. STS and LOC also respond. We will observe activity due to places in PPA. I have programmed localizing stimuli for these regions, but amygdala will be localized based on anatomy [2].

We have also considered a number of preventive controls. Existence of multiple plausible conclusions in previous studies has demonstrated the importance of a well designed experiment. Facial images will be changed so as to avoid adaption in the amygdala [18]. Requiring the subject to identify (n-AFC) the class of the image at onset of consciousness will prevent false alarms.

We expect that amygdala activation will show unconscious responses to the angry faces, while activity in FFA may change with the percept. We're interested in the moments leading up to this change. It would be very interesting if we could detect activity in one of our regions of interest that comes before the report

of a percept. This buildup could be said to lead to the conscious perception. I will learn data analysis methods for de-convolution and averaging of the BOLD signal.

There are several other professors in *CNS* with whom I would be interested in discussing the possibility of doing a lab rotation. In fact, Caltech's alignment with my research interests is one of the main advantages over other programs I have investigated. Interesting and successful science seems to be happening everywhere. Professor Shimojo's Psychophysics Lab would be an excellent place for me to further explore my interests in perception. Additionally, I am interested in applications such as facial detection and tracking interfaces at Professor Perona's Vision Group and I've looked into Andersen's research on sensory coordinate systems. I found it quite interesting that they were able to train a monkey to move a cursor with his thoughts. Of course, the common theme in these research projects is vision. I love the fact that I can *see* the phenomena and effects that I'm testing for. I'm enjoying learning more about the available research projects as I audit *CNS 186* this term. I've been fortunate in having the ability to really explore my interests up until now. I look forward to doing the same in graduate school, while also focusing on a single topic.

3 Research Experience

Rather than including additional abstracts for research prior to my senior thesis, I will describe it here. For my most recent project, which was in neural modeling, please see the attached abstract. Although these projects were not in the area of Computational Neuroscience, they have helped greatly in my academic preparation for graduate studies.

During the summer after my freshmen year, I worked with Dr. Jan Tobochnik (Kalamazoo College, Physics Chair, Editor, American Journal of Physics) in the development of Java applets for physics education. I was responsible for the programming of an applet, which simulates principles in thermal physics via a particle-in-a-box model. Through the use of systems of position and momentum equations, I simulated granular material in two dimensions. The simulation was inspired by a device called *The Boltzmann Machine*. The *Machine* consists of two platforms, one raised slightly with respect to the other. The platforms are joined with a smooth ramp and ping-pong balls are allowed to move freely within rubber bands (like a "boxing-ring"). As a ball travels up or down the ramp, its kinetic energy changes. In the simulation, this transition was modeled by changing the momentum of the particles after they crossed a central vertical line. Various interactions were tested between the particles, including both non-interactive ideal gases as well as sand-like granular material that loses momentum after each collision. My results were in agreement with those published on a physical *Boltzmann Machine*. After writing the Java applet, I was concerned with the pedagogy involved in its use. For this task, I authored a web page containing the applet as well as a series of questions for student users to answer. From this project, I found that computer simulations can be a valuable tool for Physics education, but the benefit of having these simulations requires careful testing within realistic parameter ranges.

During my junior year, I travelled to Perth, Western Australia to study at Curtin University of Technology. Curtin has a well respected Applied Physics Department as well as an extensive engineering school. While there, I studied Solid State Physics and applied my knowledge directly to a project on the *Identification and Analysis of Defects in Clay Minerals*. I worked both independently and directly with my supervisor—Dr. Robert Hart (Researcher, Applied Physics, Curtin University). My project involved analysis of synchrotron data collected at the Photon Factory synchrotron in Japan. The data was collected by powder diffraction methods. I used several computer programs to analyze the data in the form of counts of radiation vs. the diffraction angle. The programs are commonly used to determine crystallinity indices and crystallite size. The resulting data show correlations between these and bulk physical and chemical properties of the soil Kaolins. An interesting application of specialized Kaolins is the creation of lightweight, high-strength polymer cement. For further experience, I operated the Transmission Electron Microscope,

and employed Energy Dispersive Spectroscopy for the identification of elemental concentrations. Although I was involved in only the data analysis stage, this project taught me about the importance of collecting reliable data. There were situations where it would have been helpful to have data of higher resolution. Also, in the case of several samples, we found that even the capillary tubes that contained the powder to be analyzed were not pure enough to allow for unhindered diffraction data. As a result, my supervisor will need to go back to Japan to collect more data from the same samples.

Overall, my study abroad experience in Australia helped me learn to adapt to new situations. While in Australia, I took courses in several departments. Each department and course had very different expectations, which were also different to what I had grown to expect at Kalamazoo College. Additionally, there were a number of cultural differences, but in Australia the differences are not obvious. Instead, the differences are hidden and can be quite shocking when first discovered.

Upon returning to the U.S., and to Kalamazoo College, I worked as a teaching assistant for a course entitled Computational Neuroscience. Having taken the course previously from Péter Érdi, I had the experience necessary to lead a small group of undergraduate students on a project involving a simplified model of the olfactory bulb. While I was taking the course, I had done a similar project on a single neuron model. We made some progress during the ten weeks of the course, but my most important benefit from the project came as preparation for what would become my senior thesis.

4 Accomplishments and Motivations

I have come to realize that the use of several tools is often necessary to reach valid conclusions. My background in Physics, Computer Science, and Mathematics allows me to apply a number of different types of analysis. My programming skills have been invaluable in the inherently interdisciplinary field of Neuroscience. Naturally, Physics has helped to develop my problem solving skills. In the context of a Liberal Arts education at Kalamazoo College, I have been allowed to explore my interests in a way that has emphasized learning for its own sake. One might not expect Liberal Arts studies to benefit Neuroscience research, but I recently came across a discussion on one of Buddhism's fundamental principles. In one of his *CNS120* lectures, Christof Koch asked the question, "Is it possible to be conscious, but not of anything in particular?" In my Buddhism course, we discussed this many times. Incidentally, this course was most significant in my analytical writing ability. My writing ability has come a long way as I've developed it while exploring topics ranging from Impressionistic art to *Thermal Physics* and *Computational Neuroscience*. Now, people often come to *me* for help in proofreading their essays. I immensely enjoy the act of writing and now view it merely as analytical thinking, with the very last step being the actual mechanical process.

Although it may seem trivial, I think that the quarter system at Caltech, which I have also grown to like at Kalamazoo College, is the best way for me to learn in a classroom setting. I prefer to focus on a fewer subjects at a time so I can devote my full attention to them.

My peers would describe me as a motivated and goal oriented person. Recently, my desire to undertake graduate studies at Caltech has resulted in a new surge in this motivation. My motivation comes from my curiosity to discover just how far I can push myself. Because of the satisfaction I feel from a job well done, I rarely turn in work that is not my best, and I am always working to improve my knowledge when classes are not in session. Over the past few years in particular, this motivation has paid off through grants I've received for several trips abroad. These included research and presentations on several continents. For a number of reasons, I believe that studying at Caltech will help me to grow. When visiting in September, I was impressed with many of the people I met. They were sincere when discussing the strengths of the Institute as well as it's downsides. More recently, I have had similar discussions with several graduate and undergraduate students. I am aware of the problems that many students experience during their graduate career (at any institution), yet I believe that my character, determination, and interest in my research will help me through. A student I met at the library illustrates my impression of the people at Caltech. He let

me borrow his computer since I did not have a student account, and after I had finished looking up a few articles, I talked with him at length about his experiences at the Institute. He was extremely polite and willing to answer my questions, even about the smallest details.

5 Objectives

Over the past few years, I have learned to work more independently. Being able to ask the right questions is important, but more valuable is the ability to find the answers for yourself in the literature, or sometimes by just thinking about a problem. I think the ability to find answers in this manner separates Caltech students from those at some other institutions. My research in Australia and Hungary has allowed me to develop my skills for independent research. The Hungarians I worked with displayed a genuine intellectual curiosity, which I regard highly. Observing firsthand the cultural differences between the U.S. and Hungary, I have learned more about myself and my own culture. In Hungary, scientists are very well respected, and people such as John von Neumann are national heros. In Australia, I learned that I am usually more productive and creative after I take some time away from my work to enjoy the outdoors. Several times, I took breaks from my research for SCUBA diving and climbing and found that upon my return I was fully refreshed and ready to continue.

Similar to the senior undergraduate who I met at the Library, I realize that most Caltech students are very excited about their research and are happy to discuss it at any time. In classes, I am often the first to speak up to answer a question, and I am never afraid to ask when something is not clear. I have a strong desire to work with similar-minded people. Additionally, I think that cultural diversity is one of Caltech's greatest assets. Nearly everyone I've met is from a different part of the world. My recent travels have demonstrated the value in living and working with people of different cultures. As we are becoming more integrated into a global society, I think it is becoming increasingly important to be analytical of current events. Critical discussion has value even if it is only conversation among peers. We have a responsibility as a society to question our values for the purpose of making the world a better place.

While I am not able to say specifically what I will be doing after five to ten years, I am highly cognizant of the factors that will help to make me happy. I value the academic life for the freedom of thought it allows. In a career, this freedom and allowance for creativity is extremely important. I also want to have the opportunity to act as a mentor in passing on my knowledge. By helping younger generations of scientists to achieve their goals, I can give back in a way to those who have helped me. I would like to be involved with scientists in the international community as well. I think that collaboration across scientific disciplines is wonderful, and when this interaction takes place internationally, it serves to strengthen our ties with other countries as well.

6 Conclusion

As an icon of Caltech, I can personally identify with a number of Feynman's values. I feel a great need to help the younger generations of scientists to explore their interests. Similar to Feynman, I have travelled to a number of exotic locations, yet I have a desire to see more. And, although I am not a bongo drum player, I grew up playing the violin and I have a passion for SCUBA diving and adventure sports such as climbing. Feynman is probably the best example of what is possible at the Institute. In my mind, I see Caltech as the only place at which I can pursue my research goals and be surrounded by similar people who will push me to my maximum potential.

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