BETH A. LOPOUR, PH.D.
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DEPARTMENT OF NEUROBIOLOGY
UNIVERSITY OF CALIFORNIA, LOS ANGELES
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Dear Professor Sheinberg,

I am writing to apply for the tenure track faculty position in Computational Neuroscience at Brown. I received my Ph.D. from UC Berkeley in December 2009, and I am currently a University of California President's Postdoctoral Fellow at UCLA. While I am in the department of Neurobiology, my background in engineering has given me the tools to study neuroscience from a computational perspective. More specifically, I am using human electrophysiological data at multiple scales (including both single-neuron and scalp recordings) in conjunction with mathematical models to study information processing in the human brain. I am interested in how this processing occurs during normal tasks, such as short-term memory encoding and recall, and how network interactions can lead to disorders such as epilepsy. The department of Neuroscience at Brown and the interdisciplinary environment of the Brown Institute for Brain Science would be a very fruitful setting for this work. My research has already greatly benefitted from interactions with neurologists and neurosurgeons, and I would look forward to developing new collaborations with clinicians in the school of medicine at Brown.

I first had the opportunity to study neuroscience when I won an NSF Graduate Research Fellowship at UC Berkeley, and I was able to pursue a project independent of available grants. In my dissertation research, advised by Andrew Szeri, I worked with a mean-field, mesoscale mathematical model of the human cortex that can support seizure-like waves. By adding feedback and computing numerical solutions to the cortical equations, I modeled the effects of controlling seizures via cortical surface electrodes. Using the same cortical model, I was able to study human sleep states and make steps toward the prediction of seizures during sleep. I used a technique called locally linear embedding to visualize high-dimensional electroencephalogram (EEG) data in a low-dimensional space where it could be directly compared to the mathematical model of the sleep cycle. This led to a continuous representation of sleep states that could be monitored over the course of the night. By identifying states where seizures are most likely to occur, it may be possible to predict (and prevent) them. My work in this area was strengthened through collaboration with Heidi Kirsch, MD, MS at the UC San Francisco Epilepsy Center and James Sleigh, MD in the department of Anesthesiology at the Waikato Clinical School in New Zealand.

Now, as a postdoctoral fellow at UCLA, I am collaborating with neurosurgeon Itzhak Fried to study the neuronal networks that cause and propagate epileptic seizures. As part of the pre-surgical evaluation, patients with medically refractory epilepsy have depth electrodes implanted in various brain structures. Using data from these electrodes along with measures of correlation and causality, I can identify networks consisting of functional connections between brain regions. Properties of these networks can then be compared to the clinical determination of the seizure focus and used to make a prediction of post-operative seizure freedom. Finally, I can compare predicted and actual outcomes to validate my analysis. This will shed light on the generation of seizures and will allow more precise recommendations for surgical treatment.

This type of data, taken from human patients with implanted electrodes, can be used to examine a wide variety of topics related to neural information processing, in addition to epilepsy. The flexibility of the data is important because the patients are rare, and it can take six months or more to determine if the epilepsy surgery was successful. Thus, while working on the longitudinal study of epilepsy, I have been using the same data sets to study basic mechanisms of neural coding related to short-term memory and feedback signals. We have found that it is possible to do single-trial classification of feedback signals using only the phase of the low frequency local field potential. I recently presented these findings at both SfN and Cosyne, and a corresponding paper is in preparation.

My research experiences thus far have led me to encounter many interesting questions that will become the basis for my future work. The techniques for analyzing functional connectivity that I have learned in my postdoctoral work are applicable to a wide array of data types and questions, including the effects of neurostimulation and medications on neuronal networks. I am interested in continuing my work on epilepsy, more specifically studying the *temporal* evolution of these networks. For example, how do they change as a seizure approaches? What do the networks look like in different sleep stages, and how does this relate to seizure generation? I am also interested in continuing to study feedback control of epileptic seizures, with a focus on more sophisticated control and the optimization of electrodes for cortical stimulation.

Based on the faculty research interests described on the Neuroscience website, my expertise will provide the department with new research topics, as well as introduce many opportunities for collaboration with existing faculty members. First, the work of John Donoghue and Leigh Hochberg on neural prostheses would pair well with the mathematical model of implanted electrodes that I used to simulate the feedback control of epilepsy. In addition, the implementation of these prosthetic devices requires the decoding of neural signals, which I am currently studying in humans doing a short-term memory task. Second, the study of neocortical circuits and epilepsy by Barry Connors would be an interesting complement to my analysis of the human brain networks that propagate seizures. In this work, partnering with clinicians that study the treatment of refractory epilepsy, such as Andrew Blum and Rees Cosgrove in the department of Neurology, would be a great asset. Collaboration has been an essential part of my work so far, and I look forward to building new academic partnerships.

I have had the opportunity to teach in several different settings, and these experiences have made me excited to continue teaching in the future. As a graduate student at UC Berkeley, I was a TA for an introductory MATLAB programming class. I ran several lab sections, which taught me a great deal about how students learn new concepts and how to work with small groups. As an NSF fellow, I was unable to obtain any additional teaching positions because they were generally reserved for students in need of funding. This led me to pursue other ways of gaining experience, such as volunteering as a tutor and taking graduate-level courses on teaching. The techniques I have learned are applicable to several courses at Brown. Due to my engineering background, I would be excited to teach a course in Computational Neuroscience, such as NEUR 1680. I would also enjoy introducing new students to the field in a course such as The Brain: An Introduction to Neuroscience (NEUR 0010). My first experiences in neuroscience had a profound effect on my career, and I would love to provide a similar opportunity for my students.

My full application includes a copy of my CV with a list of references, research and teaching statements, and samples of published research. If you have any questions for me or would like additional information, please let me know. Thank you for your consideration; I will look forward to your response.

Sincerely,

Beth Lopour

BETH A. LOPOUR

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EDUCATION

- Ph.D. from University of California, Berkeley, CA, Mechanical Engineering, December 2009
- M.S. from University of California, Berkeley, CA, Mechanical Engineering, 2006
- B.S. from Northwestern University, *summa cum laude*, Evanston, IL, Mech. Engineering, 2004

FELLOWSHIPS AND AWARDS

- University of California President's Postdoctoral Fellowship, UCLA, 2011-2012
- National Science Foundation (NSF) Graduate Research Fellowship, UC Berkeley, 2006-2009
- UC Regents Fellowship for graduate study, UC Berkeley, 2004-2006

RESEARCH EXPERIENCE

- **Postdoctoral research**: UCLA Department of Neurobiology, January 2010-present; advised by Dario Ringach (Neurobiology/Psychology) and in collaboration with Itzhak Fried (Neurosurgery)

  Epileptic patients who have elected to undergo surgery to treat their condition are implanted with electrodes to allow clinicians to localize the seizure focus. These electrodes capture both seizures and normal activity, and thus they present a unique opportunity to directly study the human brain. I am using this electrophysiological data to identify the neuronal networks that cause seizures; my goal is to quantitatively determine the minimum amount of tissue that can be removed to disrupt the epileptic network and prevent seizures from occurring. In parallel, I am using data gathered during a short-term memory task to study the role of local field potential (LFP) phase in the coding of neural signals.

- **Dissertation research**: *Sleep dynamics and seizure control in a mesoscale cortical model*
  Committee: Andrew J. Szeri (chair), Bruno A. Olshausen, J. Karl Hedrick, Alexandre Bayen

  Using a mean-field, mesoscale model of the human cortex, I examined both feedback control for the suppression of seizures and the continuous mapping of sleep states to aid in seizure prediction. First, I demonstrated a method of feedback control that employs charge-balanced signals as a means of minimizing the potential for damage to cortical tissue. I then discussed the role of length scales in the model with regard to electrode design. Next, turning to the complex relationship between sleep and seizures, I presented a method for mapping human sleep electroencephalogram (EEG) data to a continuous range of states. More specifically, I used locally linear embedding to find a direct association between EEG data and a mesoscale model of the human sleep cycle. The results were consistent for various subjects over a full night of sleep, and the algorithm was written so that it could be implemented in real time. Because current sleep scoring consists of only five discrete stages, this technique may allow for tracking of sleep dynamics and a greater ability to predict the onset of seizures.

- Areas of expertise:
  - *Computational neuroscience*: experience with a mesoscale, mean-field model of the human cortex, exposure to neural network models, oscillations in small-world networks, and single neuron models
  - *Signal processing*: filtering and analysis of EEG and depth electrode data using MATLAB, wavelet analysis, reduction of high-dimensional data using locally linear embedding, measures of functional connectivity (e.g. Granger causality)
  - *Mathematical modeling*: numerical solution of ODE and PDE systems using MATLAB; analysis and simulation of systems with stochastic components; analysis of solution convergence
  - *Control Theory*: linear and nonlinear control theory for single and multi-variable feedback systems, control of stochastic systems, control of lumped and distributed systems
  - *Dynamics*: dynamics of linear and nonlinear systems, oscillations in linear systems, Lagrangian dynamics, bifurcations, influence of noise
- Relevant neuroscience courses:
  - Introduction to Neurobiology
  - Neural Computation and Modeling
  - Neural Mass Action and Mesoscopic Brain Dynamics
  - Methods in Computational Neuroscience, Woods Hole Summer Course
  - General Human Anatomy

GRANTS

- Title: *Mathematical modeling of nonlinear dynamics and bifurcation control of epileptic seizures*
  Funding Organization: NSF Division of Civil, Mechanical, and Manufacturing Innovation; Dynamical Systems program
  Personnel: Andrew J. Szeri (PI), Heidi E. Kirsch (collaborator), Beth A. Lopour (consultant), Jamie W. Sleigh (consultant)
  Active dates: Sept 2010-Aug 2013

PUBLICATIONS

- **Beth A. Lopour**, Abtine Tavassoli, Itzhak Fried, and Dario L. Ringach. Phase coding of feedback signals using low frequency human local field potential. In preparation.
- Abtine Tavassoli, **Beth A. Lopour**, Nanthia Suthana, Itzhak Fried, and Dario L. Ringach. Performance-monitoring signals are widespread in the human brain. In preparation.
- **Beth A. Lopour**, Savas Tasoglu, Heidi E. Kirsch, James W. Sleigh, and Andrew J. Szeri. A continuous mapping of EEG sleep states through association with a mesoscale cortical model. Journal of Computational Neuroscience, 30(2): 471–487, 2011.
- **Beth A. Lopour** and Andrew J. Szeri. A model of feedback control for the charge-balanced suppression of epileptic seizures. Journal of Computational Neuroscience, 28(3):375-387, 2010.
- **Beth A. Lopour** and Andrew J. Szeri. Advances in Cognitive Neurodynamics: Proceedings of the International Conference on Cognitive Neurodynamics, chapter 86: Spatial Considerations of Feedback Control for the Suppression of Epileptic Seizures, pages 495-500. Springer, 2008.
- Mark A. Kramer, **Beth A. Lopour**, Heidi E. Kirsch, and Andrew J Szeri. Bifurcation control of a seizing human cortex. Physical Review E, 73: 041928 (2006).
- **Beth A. Lopour** and Andrew J. Szeri. Adaptive sliding mode control of a charged particle in an ion trap. IEEE Transactions on Control Systems Technology, 17(5):1083-1095, Sept 2009.

Invited Presentations

- Society for Industrial and Applied Mathematics (SIAM) conference on Dynamical Systems, "High-resolution sleep scoring through the mapping of EEG onto a cortical state model," Salt Lake City, UT, May 2011; *recipient of postdoctoral travel award*
- Penn State University, "Applications of a mesoscale cortical model," State College, PA, March 2008

Conference Presentations

- Computational and Systems Neuroscience (Cosyne) meeting, "Phase coherence of field potentials facilitates prediction of single-trial outcome in a memory task," poster presentation, Salt Lake City, UT, February 2012
- Society for Neuroscience (SfN) annual meeting, "Low frequency phase of the local field potential predicts single-trial outcome in the human brain," poster presentation, Washington D.C., November 2011
- Society for Neuroscience (SfN) annual meeting, "Two-dimensional mapping of EEG states for higher resolution sleep scoring," San Diego, CA, November 2010
- CNS*2009, Annual meeting of the Organization for Computational Neurosciences, "Model and data-driven representations of the sleep cycle using locally linear embedding," poster presentation, Berlin, Germany, July 2009; *recipient of student travel award*
- Society for Industrial and Applied Mathematics (SIAM) conference on Dynamical Systems, "Simulation of feedback control for the suppression of epileptic seizures," Salt Lake City, UT, May 2009
- UC Berkeley Neuroscience Retreat, "Modeling and simulation of feedback control for epileptic seizures," Tahoe City, CA, October 2008
- Methods in Computational Neuroscience final project presentation, "Self-sustained oscillations in small world networks," Woods Hole, MA, August 2007
- Master's degree research presentation, "Adaptive sliding mode control of a charged particle in an ion trap," UC Berkeley, October 2006

Teaching Experience

- Teaching Assistant for Introduction to Computer Programming for Scientists and Engineers (E7) in Spring 2008; this was a course of approximately 400 students, 15 TAs, and 2 professors; I was responsible for running three 2-hour lab sessions every week, holding office hours, and proctoring and grading exams.

Professional Development

- Summer Institute for Preparing Future Faculty; 40 graduate students were admitted to this university-wide program; UC Berkeley, 2009
- Methods in Computational Neuroscience summer course; recipient of partial tuition scholarship; Marine Biological Laboratory, Woods Hole, MA, 2007

Service

- Society of Women Engineers (SWE) mentoring program; provided individual mentoring for three undergraduate mechanical engineers; Fall 2010-Spring 2011
- Co-president of the Graduate Women of Etcheverry (GWE), a group for graduate women in engineering at UC Berkeley, Fall 2006-Spring 2009
- Reading Partners volunteer, Berkeley Maynard Academy, Oakland, CA, September 2008-June 2009

REFERENCES

- Andrew Szeri, PhD
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  510-643-0298
- Dario Ringach, PhD
  Department of Neurobiology at UCLA
  dario@ucla.edu
  310-825-6606
- Heidi Kirsch, MD MS
  Department of Neurology at UC San Francisco
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Computational Neuroscience of Epilepsy: Identification, analysis, and control of epileptic networks

Research Statement of Beth Lopour

Executive Summary

Epilepsy affects roughly 1% of the world's population and carries with it enormous social and economic burden [1]. Treatment typically consists of one or more antiepileptic drugs (AEDs), but when these are insufficient to control seizures, the alternative treatments are much more drastic. For example, patients may have surgery to remove the seizing portion of the brain. However, this technique remains somewhat empirical, leading in many instances to full temporal lobectomy, and it does not always result in a cessation of seizures [2]. For this reason, cortical stimulation via an implanted device is being developed as an alternative to surgery [3]. This involves application of an electrical signal directly to the pathological tissue and does not require removal of any part of the brain.

My research focuses on making improvements to surgical intervention and investigating cortical stimulation as an alternative. It includes mathematical modeling and simulation, as well as data analysis that will be done in collaboration with clinicians and experimentalists. There are two main components:

- **Network analysis of the epileptic brain.** Analysis of physiological changes in human brain networks using computational measures of functional connectivity. This work will be based on data from actual cortical networks gathered from implanted electrodes, and it will be complemented by the creation of mathematical models for validation and prediction.
- **Feedback control of epileptic seizures**. Optimal feedback control of seizure waves via cortical surface electrodes and design of electrodes for effective stimulation. This research has natural applications to the broader fields of brain-computer interfaces, neuroprosthetics, and deep brain stimulation for the treatment of Parkinson's disease.

Because these projects combine aspects of basic science and medical research, they match funding opportunities at both NSF and NIH. Overall, I expect to make the following contributions:

1. My research will improve our scientific knowledge of epilepsy and the etiology of seizures.
2. My research will refine the clinical practices for the evaluation and treatment of medically refractory epilepsy and lead to more precise surgeries with higher success rates.
3. My research will advance the use of implanted cortical stimulation devices for the treatment of refractory epilepsy, as an alternative to surgery.
4. My research will contribute to the design of brain-computer interfaces and neuroprosthetic devices.

Background on the treatment of epilepsy

Surgical intervention for the treatment of epilepsy has received increasing attention over the past decade, yet the technique remains underutilized. Roughly 30 percent of people diagnosed with epilepsy will continue having seizures despite treatment with medication [1]; this is termed *medically refractory epilepsy*. It has been estimated that tens of thousands (and as many as 100,000) of medically refractory cases could benefit from surgery [2, 4], but only 2000 surgical procedures were performed in 1990, and that number has remained largely stable over recent years [5].

These surgeries are associated with low rates of mortality and morbidity, yet only 60-70% of patients become seizure free after one surgery (in some cases, with the continued use of AEDs) [1]. Therefore, the critical barrier to progress in this type of clinical treatment does not appear to be surgical technique; rather, it seems to be the localization of the *epileptogenic zone* (EZ). The EZ is defined as "the anatomical area necessary and sufficient for initiating seizures and whose removal or disconnection is necessary for the abolition of seizures" [2]. It is extremely difficult to identify this region, and current methods are imperfect. For example, studies have shown that the success of surgery for neocortical epilepsy is correlated to the extent of tissue removed [2], and a second surgery to remove more tissue may result in the cessation of seizures, if the first surgery failed to do so [6]. This indicates that evaluation techniques must be improved to achieve a 100% success rate while minimizing the amount of tissue that is resected.

As an alternative to surgery, cortical stimulation is a new form of treatment that is under development. It utilizes subdural cortical surface electrodes and/or depth electrodes to detect seizures and then to apply an electrical signal to disrupt the abnormal electrocorticogram (ECoG) activity. The electrical signal is directed locally to the site of the seizure and can be applied as needed with great temporal specificity [3]. Most importantly, it does not require removal of any part of the brain. With this treatment method, stimulation parameters can be tailored to the needs of each patient, and the device can be switched off very quickly if adverse side effects occur [3]. In humans, the NeuroPace RNS® System can automatically deliver pre-set (open-loop) electrical stimulation to the cortex when seizure activity is detected. This device is currently undergoing clinical trials and the company has submitted an application for FDA approval [7].

Experimental work with animals has shown that closed-loop devices may be even more effective. *In vivo* experiments on rats demonstrated that stimulation via proportional feedback can temporarily suppress seizure activity [8]. A subsequent set of experiments showed that an increase in the amplitude of the proportional control feedback gain corresponds to a decrease in seizure amplitude [9]. These initial results are promising, and they highlight the need for a detailed study of feedback control techniques and electrode design.

Research thrust #1: Network analysis of the epileptic brain

Project 1.1: Analysis of topological changes in epileptic brain networks to improve localization of the epileptogenic zone

As demonstrated in Figure 1, analysis of connectivity in the human brain typically follows a four-step process that includes recording data from multiple "nodes" (either unique brain structures or electrodes within a grid), calculating measures of correlation or causality between the nodes, creating an association matrix based on those measures, and analyzing properties of the resulting network using graph theory [10]. This technique emphasizes *functional* connections between brain regions rather than a physical quantity such as the extent of synaptic connections. This is extremely useful for conditions such as epilepsy, where seizure behavior can be found in regions with no apparent physical abnormality [11, 12].

I am currently studying epileptic brain connectivity using measurements at the smallest scale – microwires that can measure both the spiking of single neurons and the local field potential of the surrounding tissue. I am using interictal (between seizure) measurements to identify the epileptogenic zone, with the goal of making a recommendation to surgeons about which regions should be removed. This work has led to many other interesting questions. For example, how do these networks change as the seizure approaches? In cases where the seizures occur during sleep, how does the structure of each sleep stage relate to the generation of the seizure?

Based on my background with measures of functional connectivity, network analysis, and study of sleep states [13], I am well prepared to research these questions. While microwire data are rare, the techniques I have learned are applicable to data at other scales, including subdural electrodes (ECoG) and scalp electrodes (EEG). This represents an opportunity to work directly with clinicians, which has been very fruitful and instructive for me in the past. Using data from human patients, I plan to look at temporal changes in brain networks, during both sleeping and waking. By studying the networks across patients relative to their clinical diagnosis, predictions can be made about what treatments might be best. Then, by comparing my prediction to the actual treatment and outcome, I can determine the validity of the network analysis and eventually use it as a biomarker for the epileptogenic zone. This analysis will not only aid in understanding how seizures are generated, but it will help us give recommendations for effective treatments, such as surgery or electrical stimulation.

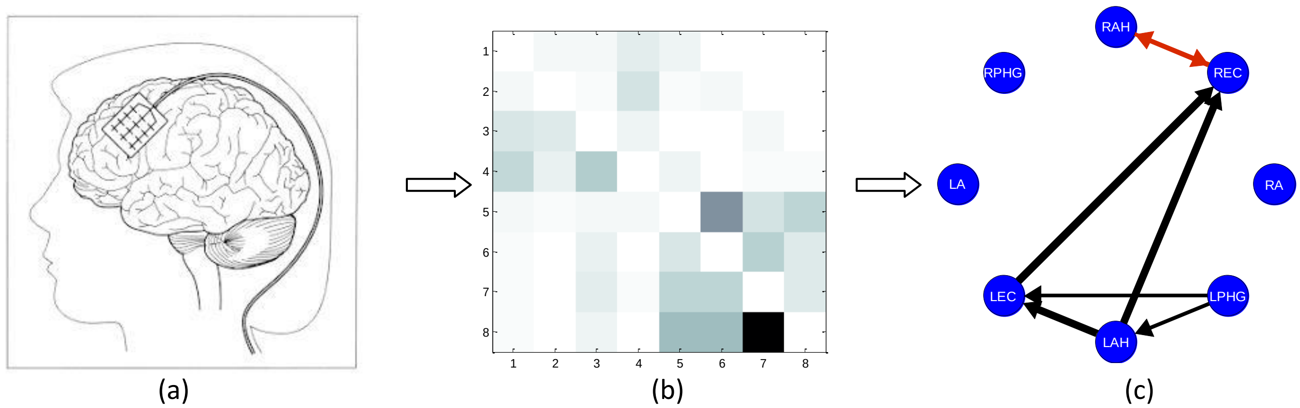

Figure 1. Connectivity analysis of the human brain follows several basic steps: (a) collect electrophysiological data, (b) calculate measures of functional connectivity and group into an association matrix, and (c) analyze the resulting network.

Project 1.2: Mathematical models of epileptic brain networks to predict the clinical outcome after treatment

While the study of human electrophysiological data is crucial to the success of this work, mathematical models can provide additional insight at no extra "cost" to the patient. Imagine we have done the analysis described above, and we have identified a network of brain regions that is causing seizures in a particular patient. If we build a mathematical model based on the topological connections and synaptic strengths provided by the network analysis, we can use simulations to answer questions regarding treatment. For example, how will the network behave if one of the nodes is surgically removed? How does it respond to strong perturbations in one of the nodes, and does this tell us anything about how seizures begin? As described in the next section, can we stop a simulated seizure by applying external stimulation to one of the nodes?

Some measures of functional connectivity have mathematical models built into them, such as Granger causality, which is based on linear autoregressive models [14]. This would be a natural starting point for my work. Other methods, such as dynamic causal modeling, are more complex but provide a spatiotemporal representation of the network [15]. I plan to develop these models in parallel with the network analysis and compare the simulation results to the actual diagnosis and treatment. Ideally, this will improve the predictive power of my work regarding clinical outcome.

Both of these projects match funding opportunities at the National Institute of Health (NIH). For example, the National Institute of Neurological Disorders and Stroke (NINDS) funds research related to epilepsy, and there is a section on Neurotechnology that directly addresses these issues of neural connectivity and localization of the epileptogenic zone. Additionally, the National Institute of Mental Health (NIMH) has a program in Theoretical and Computational Neuroscience that would be fitting for this work.

Research thrust #2: Feedback control of epileptic seizures

Project 2.1: Optimal feedback control of seizure waves using a mathematical model of the human cortex

In my dissertation work, I studied the feedback control of epileptic seizures using a mesoscale mathematical model of the human cortex (a set of nonlinear, stochastic PDEs). I designed an algorithm to suppress seizures while ensuring that the applied signal was charge-balanced to prevent tissue damage [16]. While this represented a significant improvement over simple proportional control, the development of this algorithm was fairly empirical. I would like to study the *optimal* control of waves using this cortical model.

It has been shown that a nonlinear Kalman filter can be used to estimate parameters and control spiral waves in a spatiotemporal model of cortex, while minimizing the energy required to do so [17]. This type of optimal control is ideal for the application of cortical stimulation for the treatment of seizures. For example, it would be

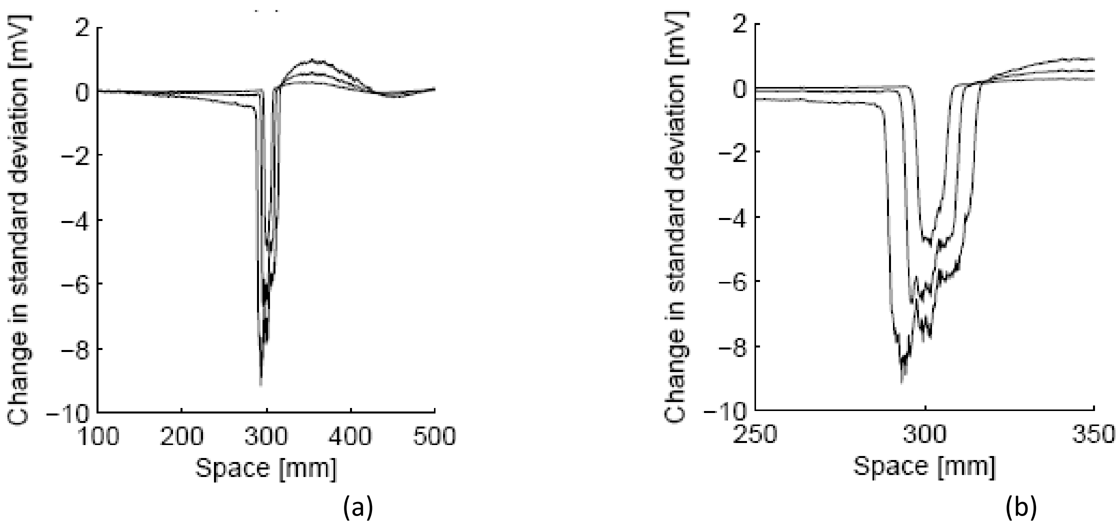

Figure 2. Results of applying feedback control via electrodes of three different sizes. (a) Change in standard deviation of the underlying cortical signal, relative to an uncontrolled traveling wave, with electrodes centered at 300mm. (b) Close-up view of the traces in (a).

beneficial to minimize the amount of time required for stimulation and minimize the magnitude of the applied signals. While it is important to suppress the seizure activity, it is not ideal to completely dampen all brain activity, as a simple proportional controller might do. Perhaps through filtering, the control can be optimized to preserve normal brain signals, based on their amplitude and frequency content. This would allow the patient to retain basic functions while the stimulation is occurring.

Because the cortical model in my work is spatially continuous and more detailed than the one used in [17], I would first remove the spatial component and focus on the temporal properties of optimal control. I would then use the results from that study to expand to a 1-D spatial simulation, and then finally to two dimensions. The spatiotemporal simulations will tie into my work on electrode design (described in the next section), and they have the potential to be tested experimentally.

Project 2.2: Design of cortical surface electrodes to maximize effectiveness of stimulation treatment

While my dissertation work focused on creating an algorithm for feedback control and a realistic model of electrode measurements, the mathematical model that I used can provide insight into other aspects of cortical stimulation. Because it is spatially continuous, we have the ability to choose both the size and spacing of electrodes on the cortex, and we can measure the effectiveness of stimulation as we vary these parameters [18].

For example, Figure 2 shows the results of simulating feedback control with electrodes of three different sizes and a traveling wave moving from right to left. Subfigure 2(b) is an enlarged version of the traces in 2(a). The electrodes are centered at 300mm and have widths of 3mm, 10mm, and 20mm; the vertical axis shows the change in standard deviation of the cortical activity, relative to an uncontrolled wave, when the control is turned on. We can see from these figures that the electrodes are able to reduce the magnitude of the electrical activity on the cortex. We note in Subfigure 2(b) that larger electrodes provide a greater amount of suppression for the same control gain, but that they are also associated with a buildup of activity on their leading edge (in Subfigure 2(a) there is a positive change in standard deviation on the right side). Therefore, there is a trade-off between the required gain, which is lower for larger electrodes, and the possibility of damaging surrounding tissue.

In addition to examining electrode size, I plan to study the optimal spacing between electrodes and the interplay between these two quantities. The model also contains a parameter related to the length scale of connections in the cortical tissue; this physiological quantity may help determine the electrode grid design. This type of research would be ideally suited to collaboration with an experimental researcher, perhaps someone working with animal models of epilepsy. This would allow us to test the model predictions. In the long term, the results of this study could be generally applicable to many other research areas, including brain-machine interfaces, neuroprosthetics, and deep-brain stimulation.

This work, related to electrode design and the feedback control of seizures, would be suitable for funding by the NSF Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET). The program in Biomedical Engineering (BME) would be appropriate, as it currently has a Neural Engineering theme. In addition, there may be opportunities through the joint NSF/NIH initiative on Collaborative Research in Computational Neuroscience.

References

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Teaching Statement of Beth Lopour

My teaching experience thus far has shown me that education is an iterative and dynamic process. While working with students in a computer programming lab and volunteering as a tutor, I found that students naturally moved through a cyclic progression as they learned new material. They would first attempt the exercises on their own, usually trying several different methods of solving the problem. Then, when they got stuck, they would seek further instruction before returning to the assignment and applying what they had learned to the next question. These steps would then be repeated for the next topic. More formally, this can be described as the *scientific learning cycle* – a continuous loop of exploration, introduction of terms and concepts, and application to new examples. In these small-group settings, I saw that there were many ways for me to guide students through this process, and I received positive feedback for my efforts. I look forward to being the primary instructor in a classroom setting, and I see many ways in which the scientific learning cycle can be successful in that environment.

The scientific learning cycle consists of three phases that are repeated for each new concept or idea [1]. First, the student explores the idea with minimal guidance, discovering different aspects of it through trial-and-error. Second, the student learns new terms and definitions from the instructor to elucidate what they saw in the exploratory phase. This often takes the form of a lecture or assigned reading. Third, the students take their newfound knowledge and apply it to novel situations, which can be accomplished through homework or laboratory assignments. It seems that most courses focus on the second and third phases of the process, and the exploration component is often missing. However, I believe that this phase of independent learning is crucial, especially for engineers who will be presented with new complex systems that they must investigate and understand. There are many ways for a teacher to encourage this type of learning and ensure that students traverse all three phases of the cycle, and I have already had a chance to implement some of them.

My first formal teaching experience was as a TA for an introductory MATLAB programming class. I taught several 2-hour lab sections, where students sat at individual computers and worked on assigned material. I did a few short lectures in front of the whole group on topics such as writing functions and the parent/child relationship between a figure and its components. However, a majority of my interactions were one-on-one or in small groups. Throughout the course, I saw manifestations of the scientific learning cycle, and I found that I could promote the process in a variety of ways. To encourage students to explore the topic on their own, I emphasized supplemental resources such as MATLAB help files and online message boards where they could read about related functions and concepts. I also demonstrated how to use the command line to test small pieces of code, so they could learn by observing concrete examples. In cases where the students were required to work with a pre-written piece of code, the debugger was a valuable tool for exploration. After working on a lab exercise for some time, students would often need further instruction to progress. This is representative of the "concept introduction" phase of the learning cycle, and I had several ways of approaching it. Sometimes, I would pull out a piece of paper and draw a diagram, write bits of pseudocode, or show a simple example; other times, I would guide the student through the problem by asking a series of step-by-step questions. When the whole class seemed to have difficulty understanding how to write functions, I made a worksheet to illustrate the concept. This diversity of techniques was useful in reaching students with a variety of learning styles, and my efforts were reflected in my positive reviews for the course. I was given scores on a scale of 1 to 5 (5 being the best rating) for nine different aspects of teaching. My average score for each category was between 4.2 and 4.6, and my overall score for teaching effectiveness was 4.4 out of 5. A full copy of my evaluation with all scores and comments is included with my application.

Because I enjoyed teaching MATLAB, I sought other opportunities to gain experience and advance my skills. As an NSF fellow at UC Berkeley, I was unable to be a TA for any additional courses, as most of those positions were reserved for students in need of funding. However, I took a graduate-level class on teaching engineering and participated in the Summer Institute for Preparing Future Faculty, where I began to develop my teaching portfolio. I looked for opportunities to practice public speaking by presenting my research in a variety of settings, including conferences, department retreats, and lab meetings. I also volunteered as a tutor with the Reading Partners program at an elementary school in Oakland. I met with a fifth grade student twice a week for an entire school year to work on reading, writing, and comprehension. While it may seem that reading skills are the farthest thing from computer programming, I saw parallels between the two experiences. Just as I did when I taught MATLAB, I found that I needed to give my student the time to read and explore the passage on his own. This allowed him to develop his own interpretation before we discussed new concepts or areas of difficulty. Then I was able to gauge his level of understanding by asking him to apply these ideas to a new reading. Again, the scientific learning cycle seemed to happen somewhat naturally, as long as I provided guidance at key points and did not constrain his independent learning.

The experiences of being a computer lab instructor and a volunteer one-on-one reading tutor have helped shape my teaching philosophy and have demonstrated the effectiveness of the scientific learning cycle. In both cases, it was clear that the process was not just a unidirectional transfer of information from teacher to student. The process was dynamic and iterative, requiring time for the student to independently learn and explore. These principles can be applied to my future teaching, even with a larger group in a traditional "lecture" style course. For example, in teaching MATLAB programming, the laboratory assignments could contain a mixture of questions focused on applying learned concepts (from the previous week's lectures) and open-ended exploratory questions (to prepare the students for upcoming lectures). In a class on controls or dynamics, the exploration phase could take the form of manipulating a physical system or predicting the behavior of a simulated system as parameters are changed. When teaching neuroscience concepts, students can use their own brain as an investigative tool by experiencing sensory illusions or taking part in short psychophysical experiments. These techniques will represent the first phase of the cycle, which is the most difficult to implement in a traditional classroom setting. The other components can be fulfilled by lectures, homework, and laboratory assignments, although I plan to use a variety of techniques, as I did when teaching MATLAB. This will reach students with diverse learning styles and will encourage class participation.

I look forward to being the primary instructor of a course, and I see many opportunities to implement these methods at Brown. Because of my background in engineering, I would be best suited to teach a Computational Neuroscience course such as NEUR 1680. I could also introduce a new course on signal processing and data analysis, as these are crucial skills for any scientist. These classes would represent an opportunity to integrate my teaching and research; as a student, my introduction to the mathematics of neuroscience was a career-altering experience, and I would like to provide that opportunity for my students. In addition, teaching basic courses to new students (e.g. The Brain: An Introduction to Neuroscience, NEUR 0010) would be another way to help get students excited about the field.

There is evidence that the scientific learning cycle is more effective than traditional methods [1], and I have found that it happens somewhat naturally in small-group settings. However, the instructor must make an effort to promote it and should not preclude independent learning by using all of the class time for lecturing. The components of exploration and investigation are particularly important, especially for young engineers who will need these skills later in their careers. I hope that by encouraging this type of learning, my students will be able to pursue their interests, find their passion, and use their abilities to make a positive impact on the world.

[1] Wankat, Phillip C. and Oreovicz, Frank S. *Teaching Engineering.* New York : Knovel, 1993.