AANS NREF/DePuy Spine One-Year Research Grant Final Report and Budget
Design of a Human Cortical Neural Prosthetic
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Interest is growing toward development of a functional human neuroprosthetic. What was once in the realm of science fiction has a very legitimate chance of becoming a reality for patients who are locked-in or suffer from devastating spinal cord injury. The concept is that cortical signals would be read and translated into intended movement in three-dimensional space. If the system is to have any practical use, it must possess certain properties, such as rapid and robust data acquisition/interpretation, compact size, and safe implementation. We do not currently know the best way to extract the signal, and my research focused on trying to determine if stereotrode configuration of a neurotrophic glass cone electrode is more robust than the standard differential method of extracellular neural recording. In the larger picture, we in the lab of Dr. Andrew B. Schwartz, are interested in studying arm and hand movement, mindful that to date no group has successfully demonstrated cortically-controlled grasping beyond simple "open" and "close" commands.

Early in my research time I learned how to train the monkeys, doing everything from transferring them to the experimental apparatus to rewarding them if they performed the task at hand properly. I was directly involved in all monkey surgeries over the past year in Dr. Schwartz's lab, where "Michigan probes" were successfully implanted and used to obtain robust neural recordings.

Since our lab had no prior experience using the neurotrophic glass cone electrode, we felt it was prudent to try it first in a rat and then proceed to implanting a rhesus monkey. (In fact, this was the first attempt to implant neurotrophic electrodes outside of the Atlanta region, where Dr. Philip R. Kennedy originally developed and implemented them.) Changing from rhesus monkeys to rats required a revision to the study protocol submitted previously to the University of Pittsburgh's Institutional Animal Care and Use Committee, which took approximately two months to be re-approved.

The area we targeted in the rat was the whisker barrel cortex, since this would allow us to obtain unit recordings without the need to train the animal. Cone electrode implantation was successful in three rats. However, in two of the rats the skull cap, which holds the electrode connector in place, fell off postoperatively despite multiple skull screws and ample dental acrylic. I believe there was simply not enough "bite" into the thin rat skull provided by the tapered titanium screws. In the future we will use non-tapered, larger diameter screws to provide a sturdier base for the skull cap. Unfortunately, one of the rats did not survive the surgery secondary to overheating. We will perform histological studies on all three rats to determine our depth of implantation and extent of neurite ingrowth into the glass cone. Although my experience thus far with the rat surgeries was frustrating, I gained considerable skill in handling/placing these electrodes and am confident that over the coming months we will be successful in obtaining unit recordings. Moreover, what was learned from my surgical experiences with both rats and monkeys over the past year will be beneficial in the future when we implant monkeys with acute (Tucker-Davis) and chronic (neurotrophic glass cone, Michigan probe) electrodes.

I reported in January 2006 that I was able to perform a three-dimensional MRI reconstruction of a monkey's brain and obtain coordinates for any point of interest. Since then I have tested the system on several different scanned volumes, and the technique has proven very accurate. It can be thought of as a poor man's stereotactic frame, where the origin is the midpoint between the earbars. The technique works because the head orientation in the MRI frame closely matches the head orientation in the frame used for surgery. After choosing a point on the cortical surface from the rendered volume, one can compute its distance from the origin in the anterior-posterior, medial-lateral, and superior-inferior directions. Efforts are underway currently in the lab to refine the technique so that slight offsets between the MRI frame and surgical frame are taken into account, which will ultimately increase the accuracy of target localization.

I spent several months in the latter half of the past year installing, wiring, programming, and debugging a Denso VSE-650 6-DOF robotic arm. This robotic arm is used to present various objects to a rhesus monkey in a rapid, reproducible, reliable, and safe manner. During these reach and grasp tasks, three-dimensional kinematic data was captured using a Vicon infrared camera system. Simultaneously, force data was recorded from sensors on the object. Eventually, neural signals from the contralateral hemisphere and EMG signals from the arm and hand will be recorded. This massive undertaking is an ongoing effort supported by a Defense Advanced Research Projects Agency (DARPA) grant and involves several people in Dr. Schwartz's lab besides myself.

My final budget worked out as follows: expenses related to the robot (Denso Robot/Zmation controller software/Bircher America safety mat/McMaster-Carr transformer) $22512.68, expenses related to the experiments (Sigma neurotrophic growth factor/Cole-Palmer thermometer and probe/Plexon 8-channel connectors) $1146.54, and expenses related to data analysis (Sharp Electronics notebook and related accessories) $3671.39. Total for all expenses was $27330.61. The remaining $12669.39 was applied as a stipend.

I am indebted to the AANS, NREF, and DePuy Spine for this opportunity to conduct important research. Although my time in the lab under the NREF grant has officially ended, my involvement in Dr. Schwartz's lab and future experiments will continue over the coming academic year. I look forward to providing you an update in the future outlining my progress and a list of published manuscripts resulting from this work.

Best Regards,

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