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Demonstration of a Chronic Brain-Computer Interface using a Deep Brain Stimulator

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Introduction: Prior brain-computer interface (BCI) research in human subjects has been limited in its ability to test systems over large time scales. Implanted BCI systems often use externalized electrocorticography (ECoG) electrodes as a signal source and are not safe for long term use (greater than a few weeks) in humans. Non-invasive systems using electroencephalography (EEG) electrodes on the scalp are not practical outside a laboratory setting because of required recalibration and inconvenient wearables such as head caps. Our approach to chronic BCI uses an FDA-IDE approved BCI platform comprised of a strip of cortical electrodes and a deep brain stimulator (DBS) currently approved to treat movement disorders. This DBS system allows sensing of brain activity through the same channels used for stimulation, providing a signal source usable over periods of months to years. We supplement this device with external hardware and software [1] to provide a chronic implanted BCI signal source, thus bypassing the extensive animal and human trials needed to develop new devices for chronic experiments.

Material, Methods and Results: One patient was implanted with a Medtronic Activa PC+S DBS for treatment of Essential Tremor (ET) in his right hand. The DBS electrode was implanted in the left ventral intermediate nucleus of the thalamus. Additionally, a Medtronic Resume II (Model 3587) 4 electrode strip was implanted over the left hand motor and somatosensory cortex (M1 and S1). One week and one month after surgery, recordings were taken from one electrode on M1 referenced to one electrode on S1 while the patient (1) moved and (2) imagined moving their right hand and right arm. The imagined movement recordings were used to generate thresholds for a BCI decoder using beta band power (16-32 Hz), which was mapped to the velocity of a cursor in a visual BCI task (a method used in many cases of sensorimotor activity based BCI as described in [2]). A screenshot of the BCI task is shown in Figure 1, and a trajectory generated by the patient to hit successive targets during an experimental trial is shown in Figure 2.

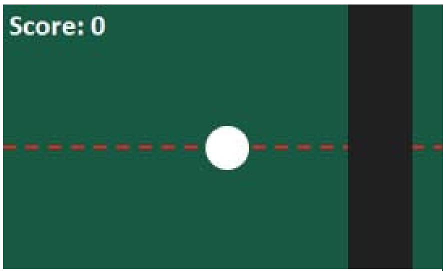

Figure 2. *Screenshot of BCI task (axis of motion denoted with dashed red line). Patient is asked to attempt to move the cursor into the dynamic rectangular targets.*

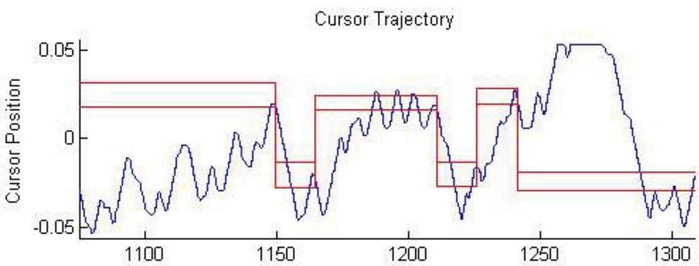

Figure 1. *Cursor trajectory (blue) generated by subject to hit task targets (red). Cursor position units relative to in-game dimensions.*

Discussion: Our preliminary results demonstrate that DBS devices are a promising platform for chronic ECoG BCI experiments. We are conducting ongoing experiments with our current subject and are approved to enroll up to five subjects. This BCI platform will allow for new long-term investigations into many areas, including how well BCI training is retained, how the ability to use a BCI may change during disease progression, and how non-naive BCI users adapt to novel decoders.

Significance: Our platform for chronic BCI enables experiments of unprecedented length to investigate how human subjects learn to use ECoG based BCI systems.

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