Studying the Effect of Subthalamic Stimulation and Dopamine-dependent Therapy on Human Behavior Analysis using LFP Signals

Adam O. Hebb; Hosein Golshan Mojdehi PhD; Joshua Nedrud MS; Mohammad H. Mahoor
University of Denver, Colorado Neurological Institute (CNI)

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Introduction

Current clinically available deep brain stimulation (DBS) therapies for Parkinson's disease (PD) are all open-loop and are unable to adapt to the ever-changing patient, medication, and disease states. **A closed-loop DBS system that utilizes appropriate physiological control based on patients' behavior may improve therapeutic results.**

In this study, **we develop a behavior classification method robust to stimulation to label patient actions even in the presence of therapy.** We investigate the effect of medication and stimulation on the increased beta power associated with PD. Three participants were implanted with DBS leads in the subthalamic nucleus (STN). The participants were cued to perform a series of 60 "button press" then "reach" actions with and without therapeutic stimulation.

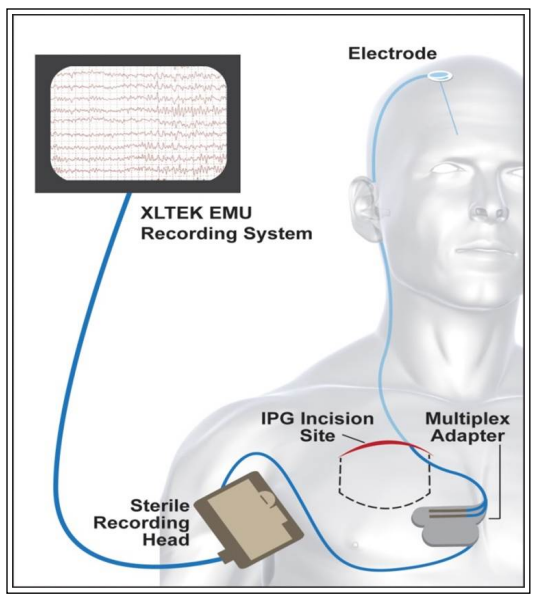
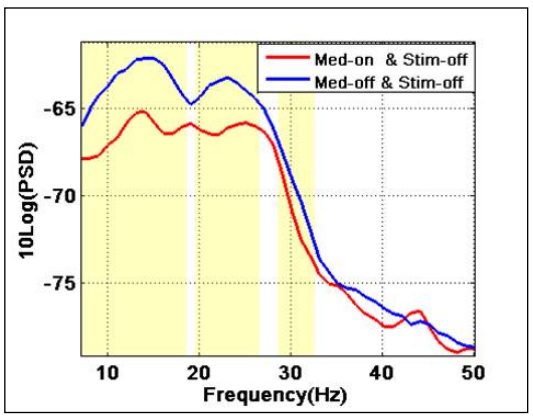


Fig. 1. Schematic of a DBS system and a data recording system (Medtronic Inc.,)



Methods

We transformed the bipolar re-referenced local field potentials (LFP) into their time-frequency representation and **used the beta frequency range (13-30Hz) as input** to a support vector machine (SVM) classifier. Additionally, we used Welch's power spectral density (PSD) estimate to evaluate the effect of the medication and stimulation on the beta power of LFPs.

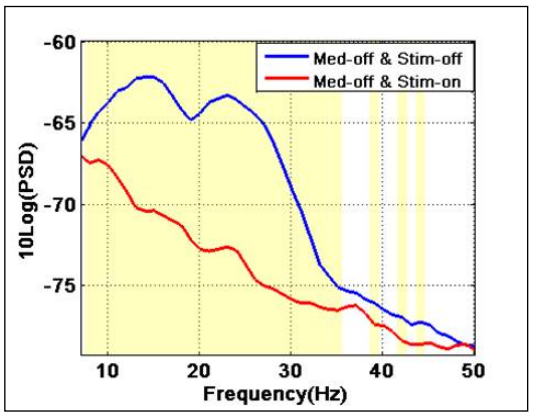


Fig. 2. Comparison between the effect of medication (top red) and stimulation (bottom red) on the beta power of LFP signals (blue) recorded from a PD subject performing "button press" trials. The graphs are obtained by averaging the PSD of 60 recordings. The highlighted yellow area shows the frequency range where the difference between two overlaid graphs (blue and red) is significant (i.e., p-value < 0.05).

Results

Recordings were performed at 12 or 24 months after DBS lead implantation surgery. Two data recording sessions were performed. subjects:

1. refrained from taking their levodopa medication for at least 12 hours
2. regularly consumed their prescribed medication dosage.

We obtained a **classification accuracy of 87%, 85%, and 87% for stimulation "off", "on", and "off & on combined"** datasets using a SVM classifier.

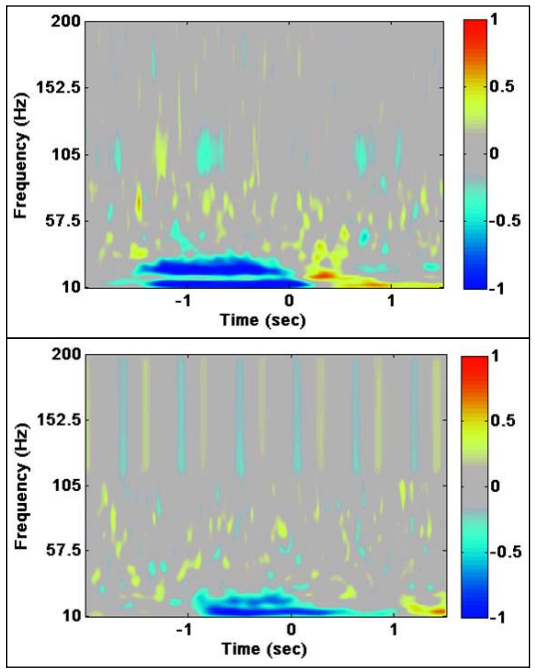


Fig. 3. The average amplitude of wavelet coefficients calculated for LFP signals of 60 "reach" trials. The results are shown for a time interval (-2,1.5)sec around each onset centered on 0sec. Top and bottom respectively shows the spectrogram obtained under stimulation "off" and "on" conditions. Consider the similarity of patterns at the beta frequency (both figures) and the artifact generated by the stimulation at f~(100-200)Hz on the bottom figure.

Conclusions

The high-frequency stimulation pulse (~140 Hz) had limited impact on the classification performance. An analysis of variance (ANOVA) for the PSDs of the four combinations of stimulation "on/off" and medication "on/off" shows **beta power is suppressed significantly when the patients take medication (p-value<0.002) or receive therapeutic stimulation (p-value<0.0003).**

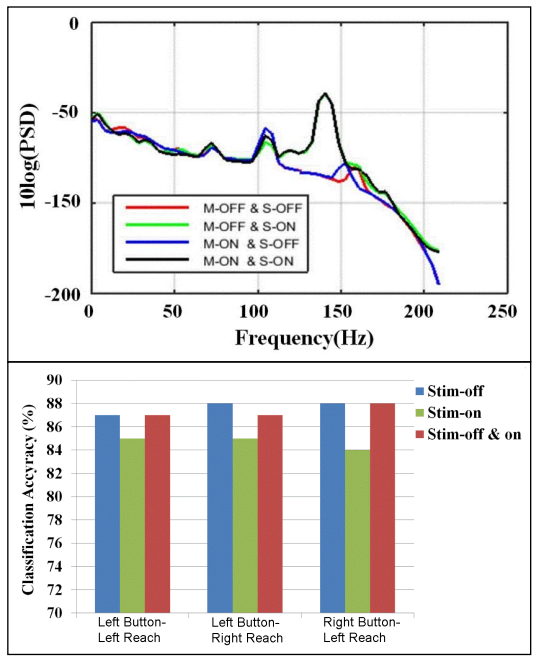


Fig. 4. Top: The artifact imposed by the stimulation pulse mainly impacts the high frequency range f~(100-180)Hz. Bottom: The performance of the SVM (RBF kernel) classifier in classifying the "button press" and "reach" tasks with different stimulation conditions.

Acknowledgement

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