Long-Term Task and Dopamine Dependent Dynamics of Subthalamic Local Field Potentials in Parkinson's Disease

Sara J. Hanrahan PhD; Joshua Nedrud MS; Bradley Davidson PhD; Sierra Farris MPAS PA-C; Monique Giroux MD; Aaron Haug MD; Rajeev Kumar MD; Mohammad Mahoor PhD; Anne Silverman PhD; Jun Zhang MD; Adam Olding Hebb MD, FRCS(C), BSc

COLORADO NEUROLOGICAL INSTITUTE

Introduction

Subthalamic Nucleus (STN) Local Field Potentials (LFP) are considered the most informative feedback signal for a closed-loop deep brain stimulation (DBS) system. Traditionally, data collection of STN-LFP in humans has been restricted to the operating room during DBS implantation.

Spectral Content of Acute and Chronic STN LFP Signals

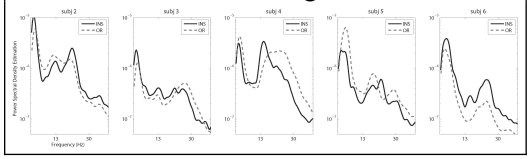


Fig 1. Power spectral density (PSD) analysis of 30-second STN LFP epochs with subject in the medication off state during rest. INS signals were recorded with an Activa PC+S system at 6 months post DBS lead implantation and OR signals were recorded with a g.USBamp (G.tec Medical Engineering, Graz, Austria) in the operating room during DBS lead implantation. Although the INS had a lower sampling rate of 422Hz compared to 4.8kHz, the spectral content was comparable. Prominent peaks in the beta frequency band were observable in both types of recordings. Early recordings with the INS system used recording parameters that were sub-optimal. Although these issues were later resolved, PSDs were limited to 40 Hz to avoid confusion.

Methods

We use the Activa PC+S system (Medtronic Inc, Minneapolis, Minnesota) to record STN-LFP in the clinic to determine the reliability of the STN-LFP over time and assess

Methods (continued)

dynamics of the STN-LFP with behavior and dopaminergic medication. Six subjects with Parkinson's disease were implanted with the PC+S system. Bilateral STN-LFP recordings were performed in the operating room and in the clinic at one, three, six, and twelve months after implant. Subjects were cued to perform voluntary behaviors including left and right hand movement, left and right arm movement, mouth movement, and speech.

STN LFP Signals Recorded from Therapeutic and Non-Therapeutic Contacts

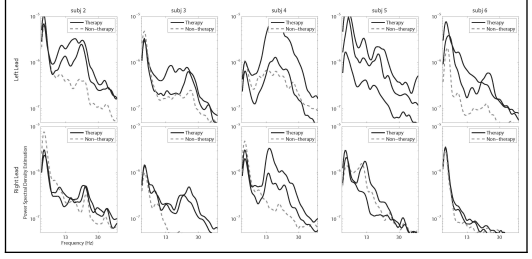
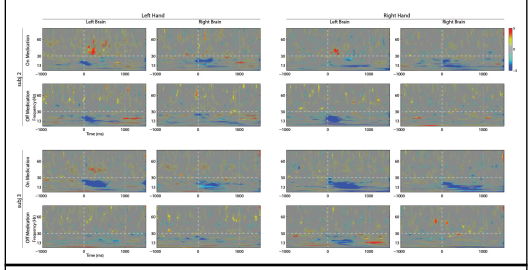
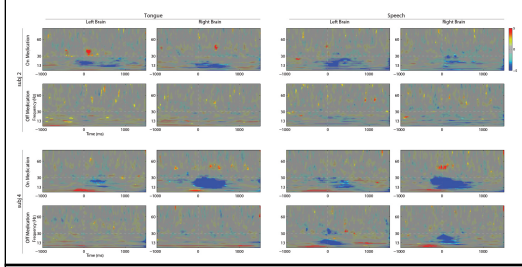


Fig. 2. PSD analysis of 30-second STN LFP epochs of all bipolar contact pairs for each subject. Therapeutic contacts were selected by the subject's neurologist as the contacts that provided the most therapeutic benefit for the subject when stimulated. PSDs across subjects were highly variable. A peak in beta power was seen in the majority of subjects and therapeutic contacts, although the size and shape varied. Notably, the non-therapeutic contacts lacked prominent peaks in the beta frequency band.

Dopamine Dependent Dynamics of STN LFP with Left and Right Button



Speech and Mouth Movement



Left and Right Reach

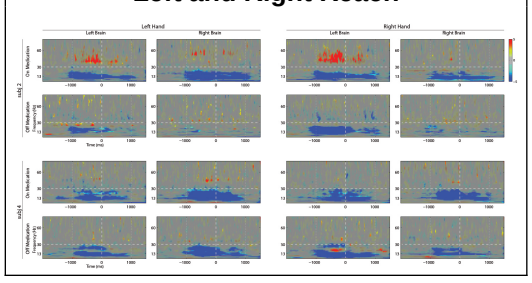


Fig 3. STN-LFP movement related power changes in Beta (13-30Hz) and Gamma (40-70Hz) frequency were consistent across multiple subjects. The STN-LFP recorded with the INS demonstrated movement-modulated desynchronization of beta and synchronization of gamma oscillations. Medication did not diminish the magnitude of the beta oscillatory desynchronization with movement. However, movement related gamma oscillatory synchronization was only observed in the medication ON state.

Stability of STN-LFP Signal over One Year

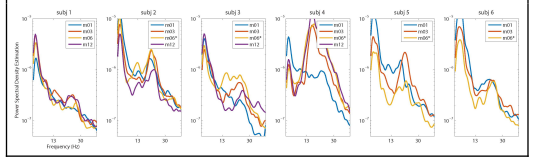


Fig 4. Longitduinal PSD analysis of 30-second STN LFP epochs with subjects during rest over one year. *Denotes recording sessions in which the subject was in the medication off state. LFP frequency content was consistent across multiple recording sessions.

Conclusions

These findings demonstrate that the PC+S system provides robust STN-LFP recordings in ambulatory patients, allowing for these signals to be recorded in settings that better represent the real-world in a variety of medication states. These results suggest oscillatory power in beta and gamma frequency bands of STN-LFP modulates with movement and medication state. Consistent with the literature, synchronization of gamma frequency oscillatory power was only observed in the medication on state, whereas desynchronization of beta frequency oscillations was readily observed in both the medication off and on state.

Acknowledgements

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