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Quantifying Neuro-motor Relationships using Deep Learning for Deep Brain Stimulation Targeting in Parkinson's Disease

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Introduction: Deep brain stimulation (DBS) of the subthalamic nucleus (STN) is an established treatment for medication-refractory Parkinson's disease (PD) [1]. Optimal targeting of the DBS electrode within the sensorimotor region of the STN attenuates many PD motor symptoms [2]. Conventional techniques for intraoperative STN-DBS targeting rely on time-intensive clinical assessments of movement-related electrophysiological signatures in real-time [3]. This standard procedure is subjective, arduous, and requires advanced clinical expertise [3]. In this study, we performed a correlation between neuronal firing rate (FR) within the STN and volitional movements tracked using computer vision (CV) to inform more objective, efficient strategies for optimizing DBS targeting and programming.

Material, Methods and Results: Datasets from 4 patients with PD (N=5 hemispheres) were analyzed. During awake DBS surgery within distinct STN subregions, we collected single neuron activity synchronized with multi-camera video recordings while subjects performed repeated trials of upper extremity motor tasks. Neural signal processing, markerless motion tracking, and deep learning-based kinematic feature extraction were used to evaluate STN neurophysiological dynamics in relation to CV-tracked movements (Fig. 1A). Repeated-measures ANOVAs compared within-subject averages of normalized FR across STN regions, with post-hoc tests applied to investigate significant comparisons. In 3 hemispheres, mean neuronal FR was highest and increased most significantly during active movement, relative to baseline activity, in the dorsolateral STN (Fig. 1B).

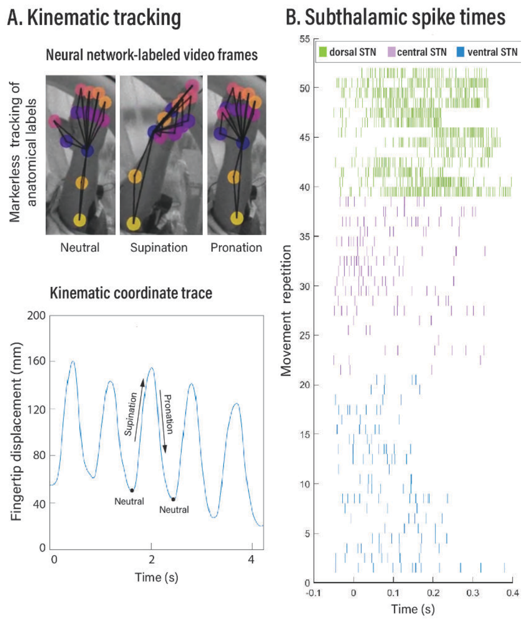

Figure 1: *A) Neural network-labeled video frames (top) and tracking of an anatomical coordinate (bottom) during repetitions of a Hand Pronation/Supination motor task; B) Raster plot of spike times during repetitions of the motor task (seen in A) at distinct STN depths: dorsal (green), central (purple), ventral (blue).*

Conclusion: Preliminary results support the hypothesis that correlation strength between neuronal firing rate and kinematic features provides a basis for predicting the sensorimotor region of the STN during DBS surgery. Computational tools that quantify relevant neuro-motor relationships may assist clinicians in optimizing DBS targeting for PD.

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