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Electrocorticography is superior to subthalamic local field potentials for movement decoding in Parkinson's disease.

Merk T, Peterson V, Lipski WJ, Blankertz B, Turner RS, Li N, Horn A, Richardson RM, Neumann WJ.
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Advances in deep brain stimulation (DBS) therapy for Parkinson's disease (PD) now focus on the development of adaptive closed-loop stimulation (aDBS) systems. Therefore, pathological activity patterns reflecting neurological symptoms are characterized from local field potentials (LFP) that can inform stimulation parameter changes. Current adaptive control policies depend on single LFP biomarkers, such as pathological beta activity in PD. Beyond single LFP biomarkers, first studies investigate the potential utility of multivariate machine learning based brain signal decoding, that may further help to refine advanced aDBS paradigms. Before a widespread clinical translation of this approach is in sight, further research is required to characterize optimal recording sources, computational methods and potential influences of pathophysiology on decoding performance. Decoding of movement kinematics for aDBS may be complementary to the beta biomarker and could advance adaptive control algorithms to refine the restoration of motor control in PD patients.

Therefore, we developed an invasive brain-signal decoding approach based on sensorimotor electrocorticography (ECoG) and subthalamic LFP to predict grip-force in 11 PD patients undergoing DBS neurosurgery. We compare grip-force decoding performance metrics across signal modalities, investigate the role of PD motor impairment and elucidate the relationship of whole-brain connectivity and model performance. We demonstrate that ECoG is superior to subthalamic LFP for accurate grip-force decoding and have systematically assessed machine learning models for their prediction accuracy. Importantly, PD motor impairment correlated negatively with grip-force decoding performance, suggesting that pathophysiology can restrict the neural capacity to encode movement kinematics in PD patients. When investigating the spatial relationship of model performance and sensing locations, basic location information alone could not predict decoding accuracy. However, using connectomic fingerprints of the sensor locations and their connectivity profile to sensorimotor and cerebellar networks allowed to predict the grip-force decoding performance of individual sensors across patients. In the future this may aid connectomic targeting of sensing electrodes for movement decoding.

Our results highlight the importance of a clinically informed interdisciplinary approach to machine learning based brain computer interfaces, as pathophysiology and clinical phenomenology will have significant impact on model performance. In conclusion, our study provides a neurophysiological and computational framework for invasive brain signal decoding and sheds light on the interaction of PD pathophysiology and movement decoding to aid the development of an individualized precision-medicine approach to intelligent adaptive DBS.

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Julian Neumann is an assistant professor for interventional and cognitive neuromodulation and junior PI in the Movement Disorders and Neuromodulation Unit at Charité. His work aims to integrate insights from PD pathophysiology, basal ganglia function, dopamine and reinforcement learning into a holistic cortex – basal ganglia – circuit model and neurotechnological treatments. He is hearing impaired and actively engaging in programs and activities to improve the scientific landscapes in terms of openness, reproducibility, diversity, equity, inclusiveness.

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