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TRR 295 ReTune

Beyond beta rhythms: subthalamic aperiodic broadband power scales with PD severity – a cross-sectional multicentre study.

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Parkinson's disease (PD) has long been associated with excessive beta rhythms in the subthalamic nucleus, inspiring beta-based adaptive deep brain stimulation (DBS). Yet studies linking beta power to motor symptoms have yielded inconsistent results. By pooling five independent datasets comprising 119 patients—far exceeding typical sample sizes—we show that these inconsistencies largely arise from insufficient statistical power. Our analysis demonstrates that more than 100 patients are required to reliably detect the association between beta oscillations and symptom severity. Beyond this large-scale validation, we identify spectral features beyond conventional beta rhythms that are critical for understanding PD pathophysiology.

Using spectral parameterization to separate oscillatory activity from aperiodic 1/f components, we found that low-frequency power and low gamma oscillations were negatively correlated with motor impairment (prokinetic), whereas low beta oscillations were positively correlated (antikinetic). Combining these features explained substantially more variance in symptom severity than low beta power alone. Furthermore, the periodic component of high beta oscillations co-localized with optimal DBS targets significantly more strongly than non-parameterized high beta power reported in previous studies. This improved spatial specificity of periodic high beta activity may inform the development of automated DBS programming algorithms.

Leveraging the common asymmetry of PD symptoms, we performed within-patient analyses comparing subthalamic activity between more and less affected hemispheres. Unlike beta oscillations, aperiodic broadband power—likely reflecting underlying neuronal spiking activity—was significantly elevated in the more affected hemisphere. Importantly, this biomarker remained stable across medication states, fulfilling a key requirement for adaptive DBS applications. Mid gamma power captures aperiodic broadband power and can be extracted in real time with existing DBS devices, thereby emerging as a promising candidate biomarker. Long-term streaming data will show whether mid gamma power and motor symptoms co-fluctuate during daily activities. Together, our results extend the predominant focus on beta rhythms and highlight the promise of mid gamma power for symptom tracking. They underscore the need for large, multicenter datasets and physiologically grounded signal decomposition methods to improve biomarker discovery in movement disorders.

Moritz Gerster

Moritz Gerster is a physicist and neuroscientist at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. As part of ReTune project B02 during the first funding period, his work focused on disentangling periodic and aperiodic components of electrophysiological signals and their relevance for Parkinson's disease. He is currently completing his PhD.

Dr. Vadim Nikulin & Prof. Gabriel Curio

Vadim Nikulin is a principal investigator at the Max Planck Institute for Human Cognitive and Brain Sciences. He leads the Neural Interactions and Dynamics group, which investigates how neural states, primarily defined by oscillatory activity, connectivity, and critical dynamics, influence information processing in the human brain. Gabriel Curio is the Head of the Neurophysics Group at the Charité. His work focuses on motor and somatosensory physiology while advancing neuronal network modeling, signal processing theory, brain–computer interfaces, innovative EEG hardware, and clinical electrophysiology in neurological disorders.

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