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Dopamine and deep brain stimulation accelerate the neural dynamics of volitional action in PD.

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Akinesia, the inability to initiate movement, is a hallmark symptom of Parkinson's disease (PD). While it can be treated with both dopaminergic medication and subthalamic deep brain stimulation (STN-DBS), the neural mechanisms underlying akinesia and its treatment remain unclear. To understand these may not only advance the understanding of PD but also help improve its treatment in the future. In an effort to explore the mechanisms of akinesia, the current study recorded brain signals from PD patients during self-initiated upper limb movements, comparing patients in three different states: OFF therapy, without medication or STN-DBS, ON dopaminergic medication, and ON STN-DBS. The research involved 25 PD patients that underwent DBS surgery in either Berlin or Beijing, with invasive brain signal recordings from the subthalamic nucleus and sensorimotor cortex.

The study revealed several critical insights. First, the results demonstrated that both cortical and subthalamic brain regions exhibit movement-related activity patterns that can be decoded using machine learning. However, decoders based on electrocorticography (ECoG) from the sensorimotor cortex significantly outperformed those based on subthalamic local field potentials. Further, the study found that the delay between movement intention and execution, as captured by both ECoG decoding output and readiness potentials, was significantly longer in the OFF therapy condition compared to when patients were ON dopaminergic medication or STN-DBS. This indicates that both therapeutic interventions shorten the delay from motor intention to execution, alleviating the effects of akinesia. Also, the study found that motor preparation was accompanied by changes in directed cortico-subthalamic connectivity, measured via Granger causality. Specifically, the administration of dopaminergic medication and STN-DBS shifted cortical drive from beta band activity (13–35 Hz), typically associated with akinetic states, to theta band activity (4–8 Hz), which is linked to more prokinetic, movement-promoting states. This shift suggests that both therapies reduce the pathological beta synchronization, facilitating motor initiation.

The findings point towards a potential mechanism for the alleviation of akinesia, where the modulation of cortical-subthalamic oscillatory networks via dopamine or DBS leads to improved movement initiation. This insight opens the door to developing adaptive DBS systems that could provide temporally targeted stimulation based on real-time decoding of motor intention, thus accelerating movement initiation and improving the quality of life for people suffering from PD.

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