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Editorial

Are beta oscillations always anti-kinetic in Parkinson's disease?

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Introduction

Parkinson's Disease (PD) is a neurodegenerative disorder clinically characterized by the prominent association of motor signs, including bradykinesia, rigidity and resting tremor (Armstrong and Okun, 2020). The pathophysiology of parkinsonian motor signs and symptoms has been deeply investigated in the last three decades. Experimental studies in non-human primate models of PD, as well as invasive neuronal recordings in PD patients undergoing deep brain stimulation (DBS), have shown abnormal oscillations in the beta band in specific basal ganglia structures, such as the subthalamic nucleus, and cortical motor areas, such as the primary motor cortex (Brown, 2007; Hahn and McIntyre, 2010; Holgado et al., 2010; Iskhakova et al., 2021). This evidence has led to the dominant hypothesis that neurodegeneration of nigrostriatal dopaminergic projections promotes abnormal beta oscillations in the basal ganglia-thalamo-cortical motor loop (Jenkins et al., 1992; Nachev et al., 2008). Accordingly, current consensus attributes to beta rhythms in the basal ganglia-thalamo-cortical motor loop the role of an anti-kinetic oscillation responsible for the main motor symptoms in PD (Brown, 2007; Iskhakova et al., 2021). However, experimental studies in healthy primates and humans have demonstrated that beta oscillations also mediate relevant physiological functions, for example, when specific networks are activated during visually-guided or corrected and goal-directed voluntary movements (Androulidakis et al., 2006; Chakrabarti et al., 2014; Jahani et al., 2020; Stetson and Andersen, 2014). The dorsal visual stream is indeed an integrated cortical network including specific fronto-parietal regions, involved in several aspects of visuo-motor integration, such as reaching in response to object motion or self-motion (Fogassi and Luppino, 2005). So far, the possible pathophysiologic role of beta-rhythms in the dorsal visual network has been poorly investigated in patients with PD during the execution of visually-guided and goal-directed voluntary movements.

The present volume of *Clinical Neurophysiology* includes the study by Sparks et al. (2022), who used electrocorticographic recordings to investigate functional connectivity between critical nodes of the dorsal visual network (i.e., posterior parietal cortex – PPC, and dorsal lateral premotor cortex - LPMC), in a cohort of 13 PD patients undergoing DBS. The authors have compared the PPC-to-LMPC functional connectivity in response to internally cued (IC) and visual externally cued (EC) actions. It is known that PD patients manifest greater abnormalities in motor planning and execution in response to IC than visual EC actions. This likely reflects at least two main pathophysiological mechanisms: 1) prominent impairment of medial cortical areas, which are mostly responsible for IC movements (Chung et al., 2018) and; 2) partially spared activation of lateral networks, including the dorsal visual network, which are known to assist visual EC movements (Galletti and Fattori, 2018). Sparks et al. (2022) compared neuronal recordings from PPC and LMPC, in patients with PD undergoing IC and EC motor tasks consisting of directional movements of a joystick-controlled by the right or left hand toward the direction of arrows on a screen. In both IC and EC trials, as main kinematic variable, the authors measured the reaction time (RT) from the visual cue to hand movement onset. As neurophysiological measure, the authors included the absolute peak of the power spectrum in the beta frequency in PPC and LPMC. Also, to assess the phase coupling and direction of information flow between PPC and LPMC, the authors considered two additional measures: the debiased weighted phase lag index (dwPLI) and the Granger causality (GC). Although the absolute power in the beta band decreased in PPC and LMPC, both the PPC-LPMC dwPLI and GC increased in the beta band and more prominently during EC than IC trials. Still, then authors found significant correlations between kinematic (i.e., RT) and neurophysiological (i.e., dwPLI) measures, during EC (i.e., the greater the PPC-LPMC dwPLI, the shorter the RT). Hence, the study by Sparks et al. (2022) suggests that the increased PPC-to-LPMC functional connectivity in the beta band reflects a compensatory activation of the dorsal visual network able to improve motor execution in PD patients (Rubinstein et al., 2002). On a more general note, the study of Sparks et al. raises doubts about the common assumption that beta rhythms are always anti-kinetic in PD.

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When considering the neurophysiological observations of Sparks et al. several possible limitations should be taken into account. For instance, the study includes a rather small cohort of PD patients and lacks a control group. A second point concerns the experimental design since also the IC trials were triggered by an external cue. Lastly, although non-demented, PD patients may manifest subclinical visuo-spatial abnormalities owing to the subtle degeneration of the dorsal visual network (Aarsland et al., 2021; Armstrong, 2015). The study by Sparks et al. (2022) however, is relevant to the debate on beta oscillations in PD. Moreover, the study opens new opportunities for innovative non-pharmacological strategies in patients with PD. A possible perspective would be to improve motor execution in PD by enhancing functional coupling in the beta band between critical nodes of the dorsal visual network through non-invasive brain stimulation. To this purpose, transcranial alternating current stimulation (tACS) has been proved to reliably modulate cortical rhythms by entraining endogenous oscillations (Guerra et al., 2021, 2020). The next steps towards the understanding of the causal role of beta rhythms in the dorsal visual stream could therefore be to examine whether beta tACS applied over specific nodes of the dorsal visual network can improve motor execution in PD patients.

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