Modeling plasticity for Neural Mass Models under tES.

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Transcranial electrical stimulation (tES) is an emerging technology for modulating cortical network activity via weak electric fields applied through scalp electrodes. Therapeutically, tES relies on plasticity to repair circuity by gently and persistently influencing dynamics through repeated sessions across weeks or months. In particular, transcranial direct current stimulation (tDCS), a modality of tES, has shown promising clinical results in several use cases: cathodal tDCS, in particular, has demonstrated inhibitory effects beneficial for conditions such as epilepsy. Conversely, transcranial alternating current stimulation (tACS) is a viable option for entraining brain oscillations, potentially addressing disorders in oscillatory circuits, such as Alzheimer's Disease (AD). Both modalities are typically applied during sessions of 20-60 minutes, repeated multiple times (10-100) on different days for long-term clinically valuable effects.

To properly design treatment for each patient, a modeling approach is needed. Neural mass modeling stands as a robust framework for describing the dynamics of average membrane potential and neuronal population firing rates in a cortical column and when combined to represent brain networks in whole-brain models. Additionally, specially designed neural mass models (NMMs) can incorporate mechanisms to replicate pathological features, such as epileptiform activity [1] or disrupted gamma oscillations [2]. Given the reliance of tES's therapeutic efficacy on enduring neural modifications, integrating plasticity mechanisms into NMMs is crucial for a mechanistic understanding of these effects.

Our research initiates with the integration of such plasticity mechanisms into NMMs. The primary objective is to evaluate both the immediate and prolonged impacts of tES in these models. The initial phase of this project is focused on mathematically integrating dynamic plasticity mechanisms into an NMM capable of simulating high-frequency oscillations. This is followed by an analysis of the stability across different conditions and parameter variations, along with an assessment of tES-induced effects. This integration of plasticity into NMMs not only enhances our understanding of tES's impact on neural dynamics but also potentially contributes to the development of more effective neuromodulation therapies for various neurological disorders.

References:

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