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Temporal Interference Stimulation for Precise Non-Invasive Motor Mapping: Simulation and In Vivo Validation

Electrical brain stimulation is vital for investigating neural function and developing therapeutic interventions. Traditional non-invasive transcranial electrical stimulation (TES) methods, while safe and accessible, are limited by diffuse activation and a lack of precision. To address these limitations, we employed Temporal Interference (TI) stimulation—a novel technique that enhances specificity with minimal current spread. We simulated electric field profiles using a virtual rat head model to predict motor maps during motor cortex stimulation and subsequently validated these predictions with in vivo experiments. Simulation results revealed that, compared to conventional TES, TI produced motor maps with higher resolution, characterized by clearly defined regions, sharper borders, and reduced overlap. The replicated in vivo experiments confirmed these findings. These results demonstrate that TI can more accurately target specific brain regions, potentially improving the efficacy of non-invasive brain stimulation therapies while minimizing off-target effects. Overall, these findings demonstrate the transformative potential of precise non-invasive targeting, paving the way for safe, low-cost treatments and experimental tools to modulate previously inaccessible brain regions.