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WHICH DIRECTION SHOULD I GO? A QUEST FOR UNDERSTANDING THE EFFECT OF TMS STIMULUS ORIENTATION ON EVOKED RESPONSES

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Symposium title: Coil orientation in TMS

Symposium description: The orientation sensitivity of TMS has long been appreciated and known to be responsible for part of the variability seen in behavioral and clinical outcomes. Yet, current clinical practice follows the same one-size-fits-all approach of orienting the coil 45 degrees with respect to the saggital plane as was instituted over 20 years ago during the infancy of the field. This orientation was chosen based on work on the hand knob that indicated this to be optimal for stimulation of a motor response notwithstanding evidence of variability between individuals. However, whether this holds true outside the motor cortex, particularly in regions of greater anatomical and functional complexity such as the dorsolateral prefrontal cortex is less clear. Needed is a fundamental understanding of the interaction between induced E-field and the underlying neuronal population and how that relates to clinical results. This symposium will present different approaches to exploring these issues, including coil engineering, electric field modeling, and neuronal modeling. Starting in the motor cortex, the speakers will address how multiscale modeling can inform our understanding of the mechanisms underlying experimental findings in MEPs. Then moving to the prefrontal cortex, speakers will explore whether electric field and multiscale modeling are sufficient to determine the optimal coil orientation in the absence of clear measures of activation, followed by a presentation of how multiple coil elements with precise inter-coil pulse timings can minimize remaining uncertainty and variability by effectively stimulating neurons positioned in various orientations. Finally, a determination based on electric field modeling of how to design studies to detect an effect comparing optimized to typical coil orientations in a large-scale clinical trial.

Abstract

The orientation of the electric field (E-field) induced by transcranial magnetic stimulation (TMS) plays a significant role in determining the magnitude of motor evoked potentials (MEP) and TMS-evoked potentials (TEP). However, fundamental mechanisms explaining the interaction of the induced E-field and the underlying neuronal populations are still largely unknown. We recently entered a quest to understand and describe neurophysiological and physical factors affecting the effect of the E-field orientation on the MEP and TEP. We developed a dual-coil TMS transducer capable of fast and accurate electronic control of the induced E-field orientation. With this transducer, we could scan the effect of stimulus orientation on TEPs and MEPs in single and pairedpulse protocols with unprecedented precision and accuracy. We further compared the experimental data with simulations of responses in realistic neuronal and brain models. Our results show that the spatial distribution of MEPs on the target muscle strongly depends on the Efield orientation. Furthermore, the simulations with realistic models indicate that multiple factors are needed to match closely the experimental data, such as the extent of the stimulated cortical area, E-field distribution, and neuronal population alignment relative to the cortical surface. Our studies provide relevant insights into how the physical properties of a TMS pulse interact with neuronal mechanisms of motor output generation and can be the basis for improving the targeting and effectiveness of TMS clinical treatments.

Research Category and Technology and Methods

Basic Research: 10. Transcranial Magnetic Stimulation (TMS)

Keywords: TMS, orientation, EMG, EEG

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Abstract key: PL- Plenary talks; S- Regular symposia oral; FS- Fast-Track symposia oral; OS- On-demand symposia oral; P- Posters

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RECENT ADVANCES ON TMS ORIENTATION OPTIMIZING BASED ON INDIVIDUALIZED ELECTRIC FIELD ANALYSIS

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Abstract

Transcranial magnetic stimulation (TMS) activates target brain structures in a non-invasive manner. The optimal orientation of the TMS coil for the motor cortex is well known and can be estimated using motor evoked potentials. However, there are no easily measurable responses for activation of other cortical areas and the optimal orientation for these areas is currently unknown. We overview recent efforts on large-scale computational simulations investigating the induced electric field orientation in the brain for optimized TMS coil orientations with aim of development universal optimal coil orientations for facilitation of TMS on clinical applications or preferable personalized computational analysis. Furthermore, we will discuss how optimal orientation of the E-field and initiation of the neuron activation based on multiscale computational analysis inform us about the TMS mechanisms of activation.

Research Category and Technology and Methods

Basic Research: 10. Transcranial Magnetic Stimulation (TMS)

Keywords: TMS, orientation, electric field

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LAB TO CLINIC: APPLICATION OF ROTATING FIELD TMS

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Ahstract

The importance of the orientation of the electric field induced by TMS with respect to the brain anatomy and the underlying neuronal units is becoming increasingly apparent. While some brain structures, like the motor cortex, have highly ordered axonal projections, other important areas like the DLPFC are intrinsically disordered. Stimulation in brain regions where a preferred axonal orientation does not exist may thus be difficult and unreliable. Only recently has attention been focused on how different TMS pulse shapes and protocols will affect stimulation in disordered areas of the brain, with studies such as those presented by others in this symposium.

In recognition of the importance of orientation, the potential of rotationally invariant forms of TMS to minimize the variability of stimulation presents itself as a means of improving clinical outcomes. This talk will focus on a form of TMS known are rotational field TMS which uses an approach of multiple coil elements with precise inter-coil pulse timings to induce an electric field that essentially rotates around the plane. The basis of the technique will be described, while experimental evidence in the motor cortex will be presented showing its effectiveness and potential. This approach can potentially improve both the inter-subject reliability of TMS and its efficacy in treatment. Future goals and limitations of the approach will be discussed.

Research Category and Technology and Methods

Translational Research: 10. Transcranial Magnetic Stimulation (TMS)

Keywords: TMS, orientation, rotational field

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