simulation accuracy based on MRCDI data, serving as further proof-of-principle of the usefulness of the new approach.

Research Category and Technology and Methods

Translational Research: 8. Transcranial Alternating Current Stimulation (tACS)

Keywords: Volume conductor modeling, Magnetic resonance current density imaging, Medical image segmentation, Finite-element simulations

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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

FS2c.6

THE ORIGIN OF I-WAVES: COMPUTATIONAL NEURONAL NETWORK MODEL OF THE CORTICAL COLUMN RESPONSE TO TMS

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Abstract

Transcranial magnetic stimulation (TMS) is a promising tool for neuromodulation due to its non-invasive application and its efficacy in treating disorders such as depression and obsessive-compulsive disorder. However, there are still knowledge gaps in how TMS stimulation settings relate to the neural elements activated and the propagation of the activation due to the neural circuitry. Understanding these relations could help to design better TMS protocols to achieve a desired therapeutic effect. Towards this end, we have constructed a neuronal network representing a single column within motor cortex and used particle swarm optimization (PSO) to identify parameter sets that can reproduce TMS-induced activity from epidural corticospinal recordings. The neuronal network model included layers 2/3, 5, and 6 with excitatory pyramidal neurons (PNs) and inhibitory interneurons in each layer, which were modeled as leaky-integrate-and-fire neurons. Afferents to these layers were also included. Connectivity was derived from anatomical data resulting in intra- and inter-laminar connections that were dependent on layer and cell type. TMS activation was modeled as the proportion of neurons that generated an action potential due to a TMS pulse. PSO was used to identify parameter sets that resulted in dose–response curves and synaptic weights that recreated the corticospinal responses to single TMS pulses that were applied to motor cortex. The optimization process determined parameter sets that could recreate corticospinal responses with or without a D-wave. The same parameter sets could also express an appropriate cortical silent period. A sensitivity analysis of the optimization results demonstrated that the D-wave and I1-wave were sensitive to distinct parameters, but later I-waves were correlated and had a shared dependence on many parameters. Direct activation of layer 5 PNs was necessary to elicit D-waves, but direct activation of layer 2/3 PNs was required for the generation of I-waves for both cases.

Research Category and Technology and Methods

Translational Research: 19. Modeling and computational methods

Keywords: Transcranial Magnetic Stimulation, I-waves, Motor cortex, Neuronal network

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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

FS2c.7

AN EFFICIENT AND EASY-TO-USE MODEL TO DETERMINE THE STIMULATION THRESHOLDS IN TRANSCRANIAL BRAIN STIMULATION AND ITS APPLICATION TO TMS MAPPING

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Abstract

The extension of current models in the field of transcranial brain stimulation beyond the estimation of the electric fields is elementary to improve our understanding of the underlying stimulation processes and adds to the accuracy of targeting and mapping procedures. The key question current endeavors try to answer is how the electric field modulates the behavior of neuronal structures in the brain. To answer this question, the integration of highly detailed descriptions of single neurons into existing electromagnetic field models is necessary, resulting in models covering multiple scales. The construction of such models is very complex and requires large amounts of computational effort. This limits their application in current studies, especially mapping and targeting procedures, significantly.

In this talk, we present the derivation of a highly efficient and easy-to-use model for coupling the electric field into neural structures and its application in TMS mapping. For this purpose, we performed extensive simulations with detailed models of numerous realistic L2/3 and L5 pyramidal cells and, from there, derived a fast and efficient mean-field approximation, exhibiting a relative error of only ~1%.

We applied the model to TMS mapping of the generation of motor evoked potentials in the hand area of M1, and compared it to the classical model, where the electric field serves as proxy for the neuronal excitation. We show that including the coupling model improves the mapping results in that they become more focal and spurious deflections at unphysiological locations disappear.

Research Category and Technology and Methods

Translational Research: 10. Transcranial Magnetic Stimulation (TMS)

Keywords: Transcranial magnetic stimulation, Modeling, Dosing, Coupling model

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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

FS2c.8

BIOPHYSICAL NEURAL MODELING OF EEG WITH THE HUMAN NEOCORTICAL NEUROSOLVER SOFTWARE TO GUIDE INTERPRETATION AND DESIGN OF NON-INVASIVE BRAIN STIMULATION

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Abstract

Electroencephalography (EEG) is a leading method to read out the effects of non-invasive brain stimulation (NIBS) on neural circuit dynamics. However, it is difficult to infer the underlying cellular and circuit-level origins of these macro-scale signals. This limitation hinders the use of EEG to interpret the impact of NIBS on circuit dynamics and hence our ability to use these signals to develop principled brain stimulation paradigms. To address this need, we developed the Human Neocortical Neurosolver (HNN: https://hnn.brown/edu), a user-friendly neural modeling tool designed to help researchers and clinicians interpret the cellular and circuit level origin of EEG-measured signals based on their biophysical origin. The foundation of HNN is a detailed model of a canonical neocortical circuit, with layer specific thalamocortical and cortico-cortical external synaptic inputs. HNN has an interactive graphical user interface that enables direct comparison between recorded and simulated EEG signals, and simultaneous visualization of microscale activity, including responses in different layers, cell spiking activity, and somatic voltages. These microcircuit details provide multiple dimensions over which model-derived prediction can be further validated. HNN is designed around workflows to study commonly measured EEG signals, including evoked responses and low frequency brain rhythms.

Recent studies have been applying HNN to examine the impact of NIBS on neural circuit dynamics by examining induced changes in EEG measured evoked responses and brain rhythms. In this talk, I will give an overview of this tool and describe studies using HNN to interpret the impact of transcranial magnetic stimulation (TMS) on neural circuit dynamics and behavior. I will describe TMS-EEG studies focused on healthy perception and treatment for neuropathology, including major depressive disorder and post-traumatic stress disorder. Lastly, I will discuss challenges and