ROBERT J. & NANCY D. CARNEY
INSTITUTE FOR BRAIN SCIENCE
BROWN UNIVERSITY

Biophysical Neural Modeling of EEG to Interpret the Impact of TMS on Brain Dynamics

Danielle D. Sliva[1], Carmen Kohl*[1], Dylan S. Daniels[1], Iris Peng[1], Julia Ostrowski[1], Rahul Jayaram[1], Stephanie R. Jones[1,2]*
* These authors contributed equally to this work
[1]Department of Neuroscience, Brown University
[2]Providence VA Medical Center, Center for Neurorestoration and Neurtechnology

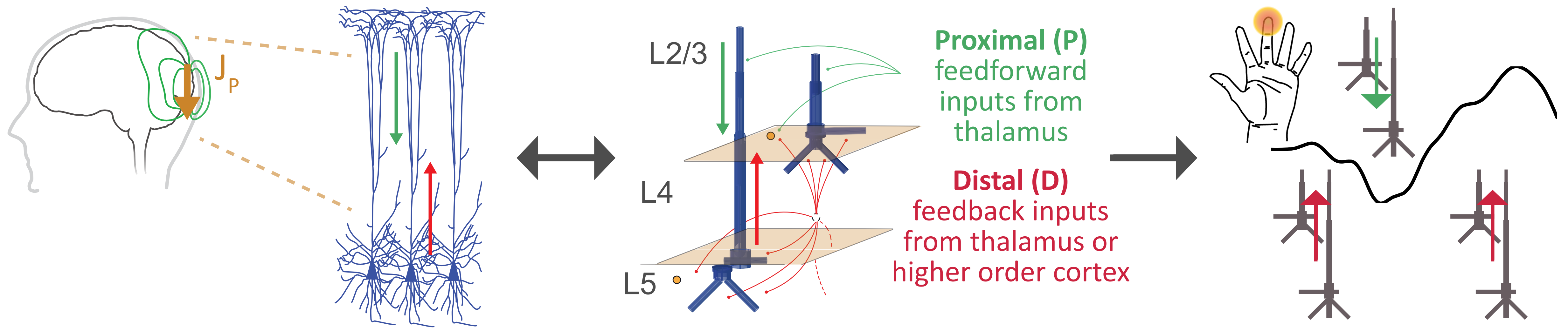
hnn.brown.edu

Background

Interpreting the effects of TMS on neural circuits is challenging but crucial to develop impactful stimulation paradigms. TMS-EEG provides a readout of fast timescale cortical dynamics, however recent evidence suggests that peripheral sensory responses dominate TMS-evoked potentials (TEPs)[1]. Earlier (<60-80 ms) rather than later TEP components are more likely to reflect focal cortical responses to TMS[1-3].

Human Neocortical Neurosolver (HNN)[6]: A Neural Modeling Tool that Links EEG Signals to Underlying Cellular & Ciruit Mechanisms

Building from previous work which identified mechanisms underlying tactile evoked response potentials (ERPs), here we use HNN[6] to deconstruct individual contributions of peripheral somatosensory and focal cortical stimulation to local circuit dynamics in primary somatosensory cortex (SI).



HNN simulates primary currents (J_P) underlying EEG signals, which reflect net current flow within pyramidal neuron dendrites.

Its cortical circuit model features canonical architecture and synaptically coupled excitatory and inhibitory cells. Layer-specific inputs represent signals from other brain regions that push current flow up/down the dendrites.

Previous work in the Jones lab has shown that a specific sequence of inputs (P-D-P) to the local network in SI generates the tactile ERP[5].

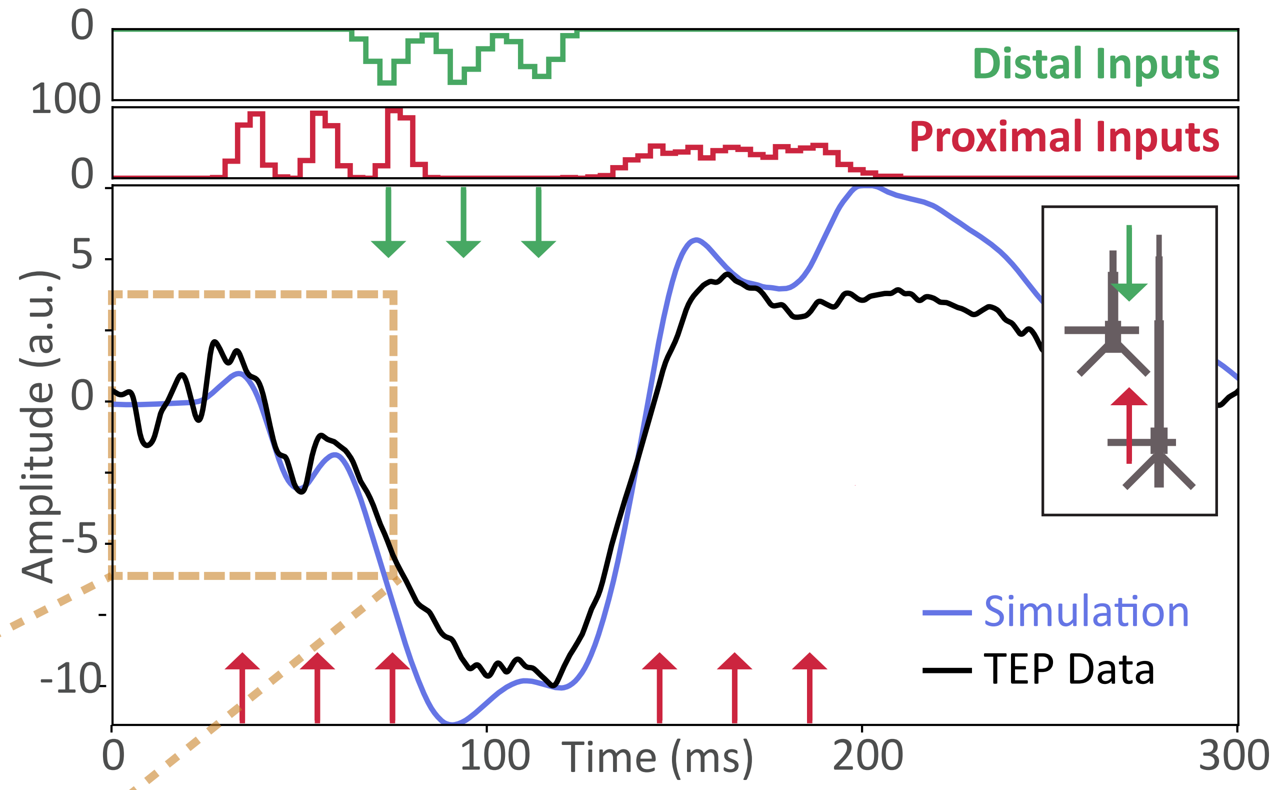
Results

HNN Reproduces Burst TEP in SI with Same Inputs that Generate Tactile ERPs[5]

To model the 3-pulse TEP, we simulated the P-D-P input sequence previously shown to model somatosensory ERPs[5] (3-pulse burst: 3x P-D-P).

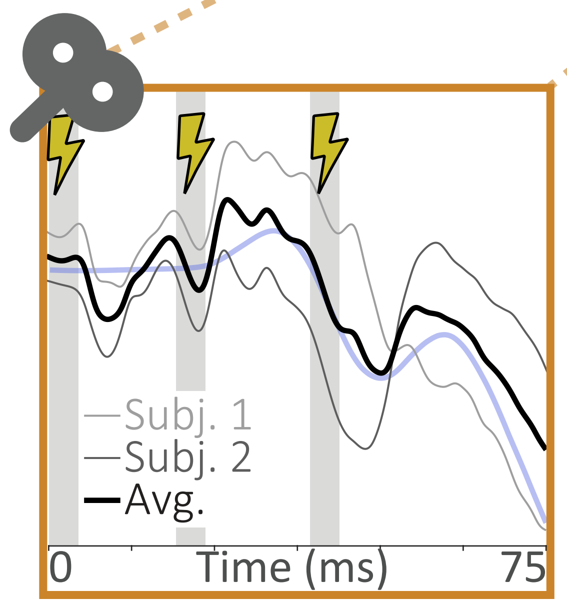
Simulating these inputs associated with tactile responses led to a waveform that showed similarities with the TEP, suggesting that later components (>60 ms) reflect peripheral tactile information from TMS pulse delivery.

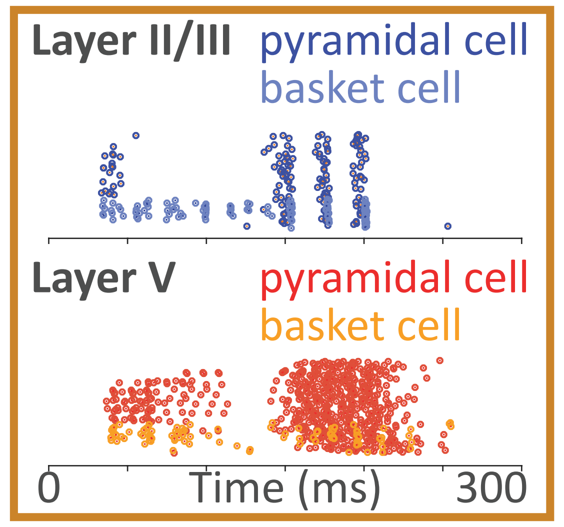
Early components (<60 ms) were visible in the recorded data but not yet captured by the model, and may contain non-sensory information.



TMS-EEG Reveals Short-Latency Dynamics

EEG data was recovered within 4 ms after each TMS pulse, with similar waveforms across subjects (grey=single subjects, black=average between subjects).



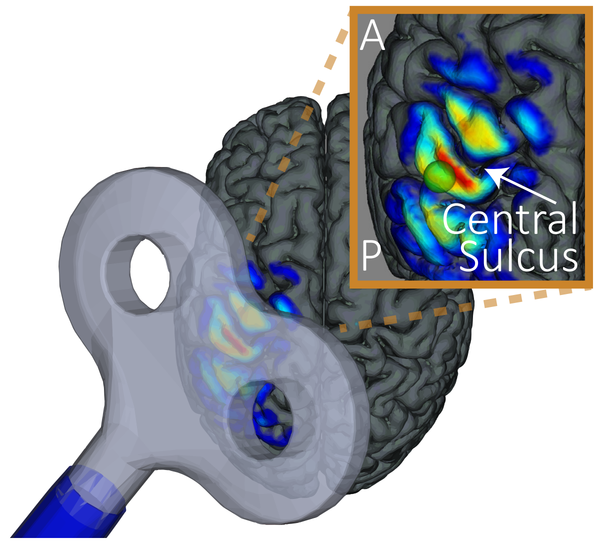


HNN Reveals Microcircuit Activity

Modeling neural signals in HNN reveals underlying dynamics, e.g. simulated layer- and cell-specific spiking activity (spike raster plot, left).

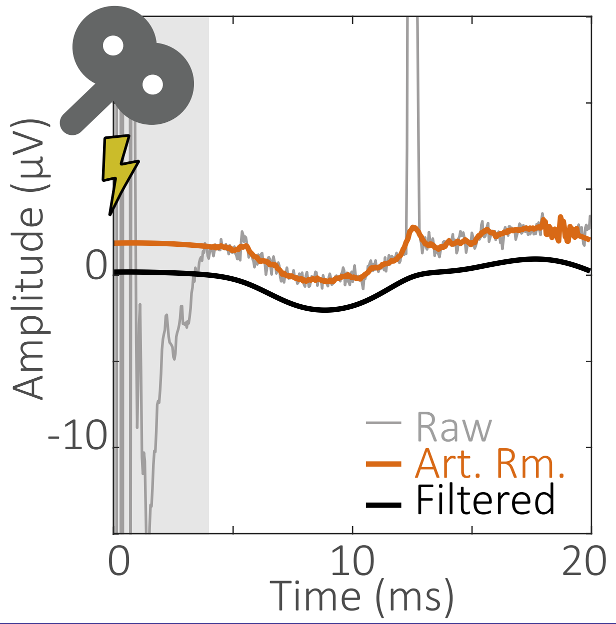
Methods

EEG Acquisition with Concurrent TMS to Assess Circuit Dynamics Evoked by TMS Pulse Bursts



TMS: 3-pulse "bursts" (20 ms ISI) were delivered over SI (Brainsight & SimNIBS, see left) at 80% active motor threshold with a Magstim Biphasic Rapid[2] and D70 coil.

EEG: A Brain Products actiCHamp Plus (25kSPS) system was used with 64 passive electrodes (impedances <5Ω).



Artifact Removal: TMS pulse (-0.05:4 ms, grey shaded area) and recharge artifacts were removed (orange) from the raw signal (grey), which was then filtered[4] (black). <30% of trials remained after visual inspection. n = 2; 34 & 44 trials.

Conclusions

→ Neural modeling shows that later components of the TMS burst-evoked waveform can be simulated in the same way as the tactile ERP[5], suggesting it is strongly impacted by peripheral somatosensory information. Early components (<60 ms) were clearly visible but not yet reproduced in the model. They are likely not influenced by peripheral input, but rather reflect focal TMS-driven circuit dynamics within SI.

→ We are able to resolve early components of the TEP within 4 ms of a TMS pulse, allowing for investigation of circuit dynamics within TMS pulse bursts using HNN.

→ Future efforts will focus on simulating early TEP components to assess the local impact of TMS within SI, and the dynamics of local circuit activity during a TMS pulse burst.

References & Funding

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