Modulation of stimulus fields in a computer model of the thalamocortical system

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1. Introduction

Microelectrode arrays allow recording and stimulation of *in vivo* neurons. However, the small number of electrodes typically used (<100) limits the amount of information and control they can provide. In contrast, computer models have no such limitations. Here, we validate a thalamocortical model by comparison with *in vivo* data, and use it to predict how microstimulation (MiSt) will affect stimulus field properties.

2. Methods

- **Experiment:** Microelectrode arrays were implanted in the somatosensory cortex of two macaques. Natural touch stimuli were applied to the hand both before and after MiSt.
- **Simulation:** The model consisted of event-driven, rule-based single-compartment thalamocortical neurons (Figs. 1 and 2). Connection probabilities are distance-dependent, while weights change via spike-timing-dependent-plasticity (STDP).

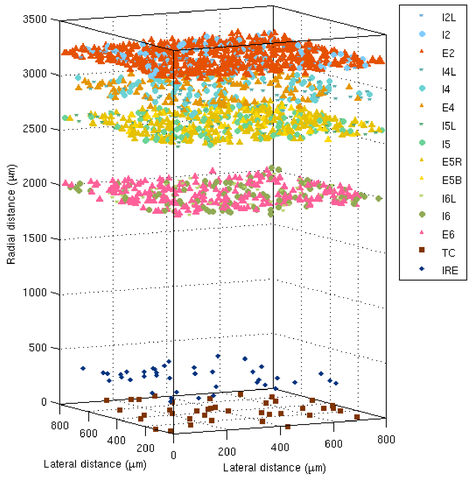


Fig. 1: Structure of the model. 15 cell types were distributed across 6 cortical layers and the thalamic reticular and relay nuclei, for 1980 cells in total.

E=excitatory pyramidal, I=inhibitory interneuron, L=low-threshold spiking, TC=thalamocortical cell; IRE=reticular nucleus cell.

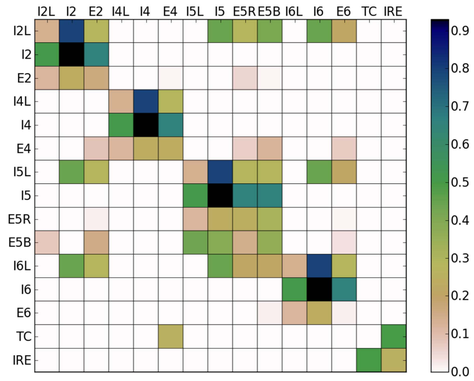


Fig. 2: Connectivity between cell types (defined in Fig. 1); the color indicates the connection strength. Note strong intra-laminar connections (along diagonal).

3. Results

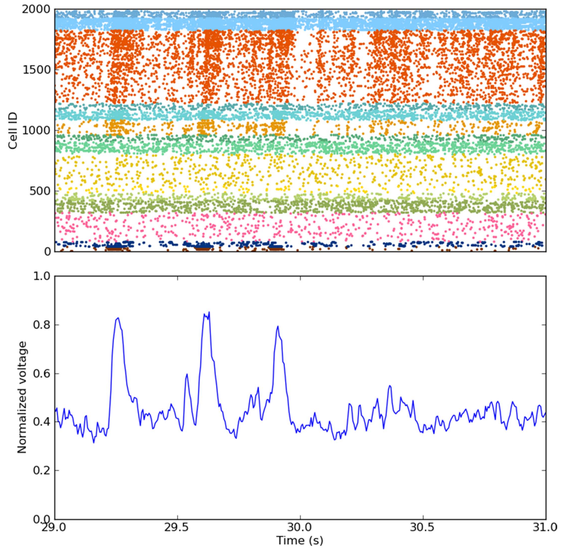


Fig. 3: Simulated spike raster (top) and local field potential (bottom). Three "natural touch" stimuli are visible here, and each results in pronounced increases in firing rate and voltage. Upon initiation of the stimuli, the model shows habituation via STDP (not shown).

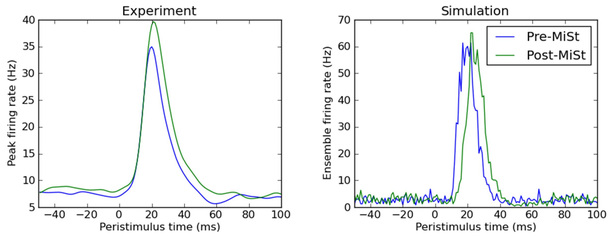


Fig. 4. Neuronal firing rates before and after MiSt. Both experiment and simulation show peak firing approximately 20 ms after stimulus onset; stimuli following microstimulation have a later, higher-amplitude peak.

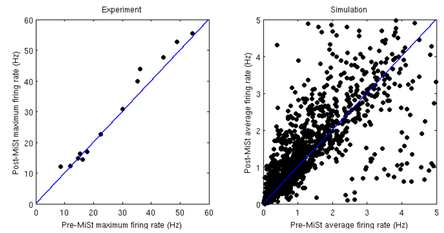
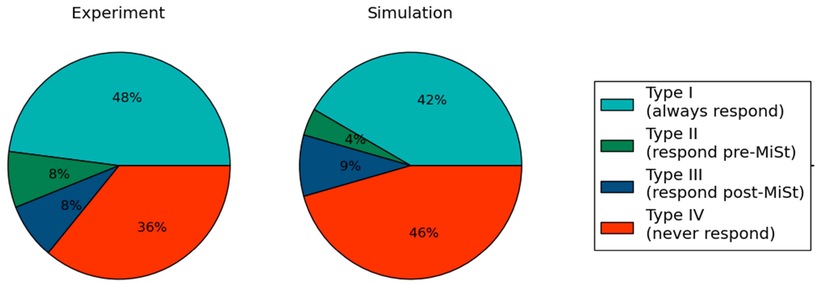


Fig. 5. Firing rates before vs. after MiSt. While the trend (higher firing in the latter) is similar in both plots, the simulation provides access to >100 times as many cells.

Fig. 6. Percentage of cells that respond to natural touch stimuli (defined as firing rates >3 SD above the mean). The majority of cells either respond both before and after MiSt (light blue) or do not respond at all (orange).



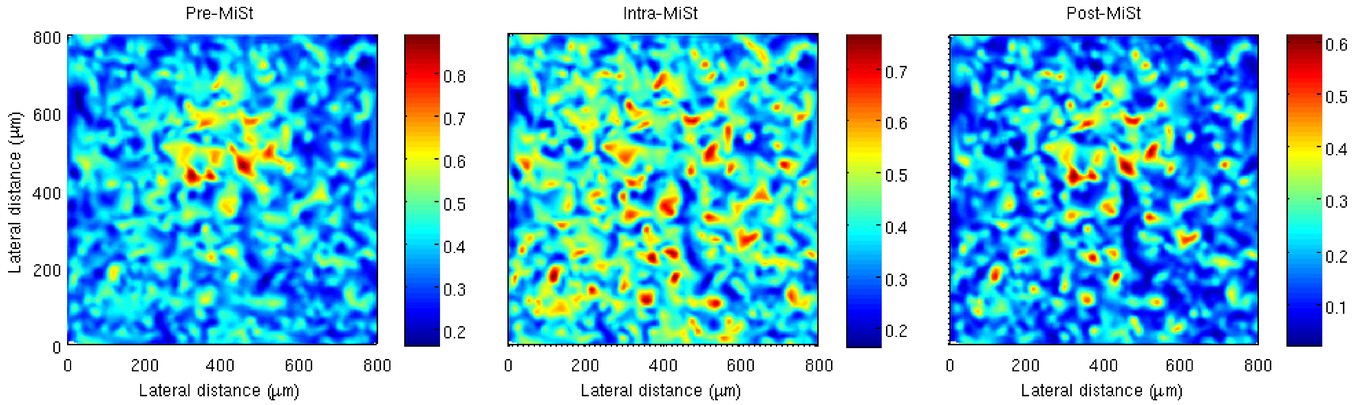


Fig. 7. Simulation of natural touch stimulus fields before (left), during (middle), and after (right) MiSt; colors show log firing rate. Prior to MiSt, the stimulus field is clearly defined. There are no natural touch stimuli during MiSt, and no stimulus field is visible. After MiSt, the stimulus field is less clearly defined, and pockets of high-amplitude firing have emerged outside the original stimulus field.

4. Discussion

- We have demonstrated that a large-scale computer model of the thalamocortical system can replicate multiple aspects of *in vivo* dynamics, including firing rates, stimulus-induced modulations, and higher-order properties.
- The model predicts that microstimulation will reduce the size and amplitude of the stimulus field associated with natural touch.
- Future work will focus on the development of a combined somatosensory-motor cortex model to control a virtual arm during grasping movements.

Reference

Neymotin SA, Lee H, Park E, Fenton AA, Lytton WW (2011) Emergence of physiological oscillation frequencies in a computer model of neocortex. *Front Comput Neurosci* **4**:19.

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Further information

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