Temporal Interference Simulation Drives Polarization in a Computational Neuron Model

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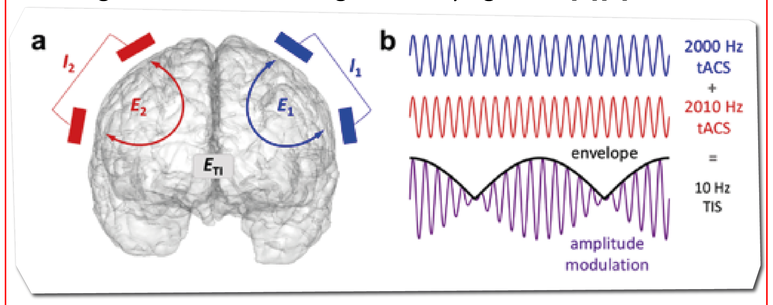
Introduction

- Temporal interference (TI) stimulation works by applying two slightly different high-frequency alternating currents to the brain.
- Intersecting currents create a low-frequency amplitude modulation envelope that can stimulate neurons in deep brain regions without affecting the overlying cortex[1][2].



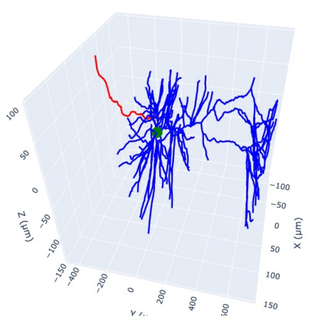
a) Diagram of TI set up on Brain b. Signal breakdown of TI beat (10 Hz) and carrier (2005 Hz) frequency creating the envelope signal

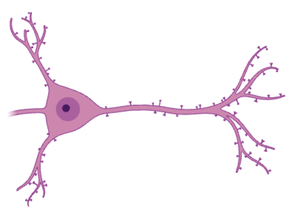
Objectives

- Provide evidence the model is accurate and behave in a normal fashion.
- Display the effects of TI in a morphologically accurate model when periodicity is showed.

Methods and Model

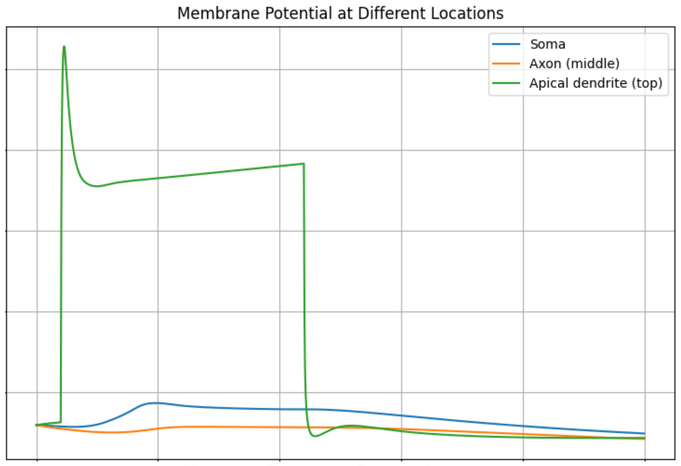
- In this study, we used the NEURON software within a Python Integrated Development Environment to simulate three-dimensional model neurons sourced from NeuroMorpho and ModelDB repertory.
- Using a simple current clamping simulation (bottom left), the model and its conductance's were validated to behave naturally.
- Axon in red, Soma in green , Dendritic and apical tree in blue.

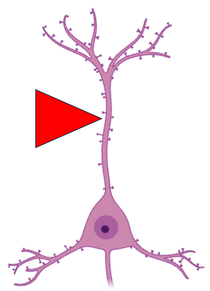


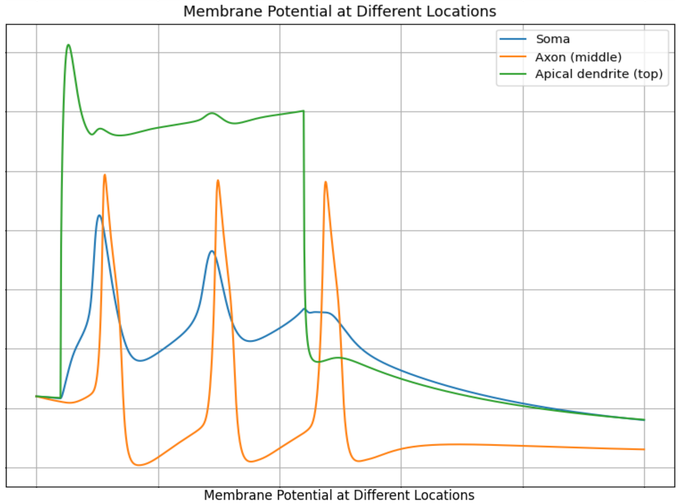


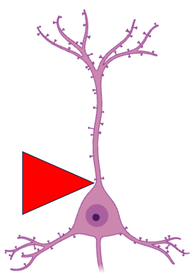
Model

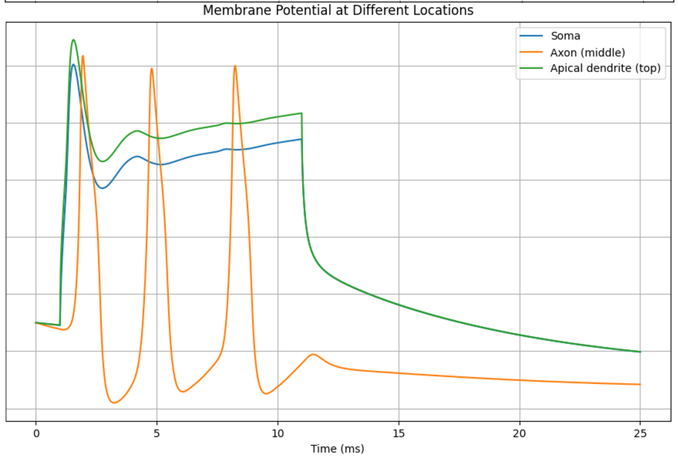
- This study used a morphologically accurate layer 5B corticospinal neuron from a mouse study with conductance : I_A; I_h; I_{KD}; I_K,I_{Ca}; I_L high threshold; $I_{Na,t}$; I_N; Ca pump; K_{ir} channel.

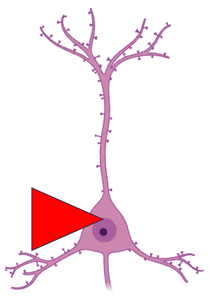






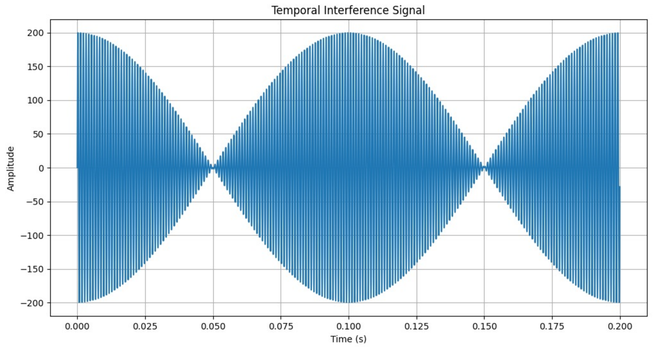




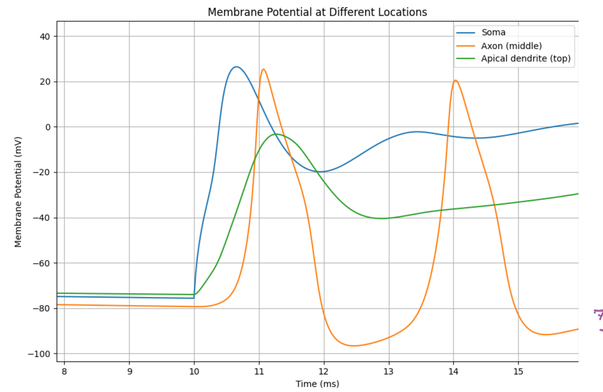


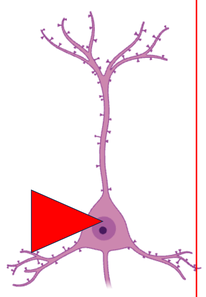
- The red triangles show the stimulation focal point for each graph
- The cell shows morphologically accurate behavior, firing properly and accurate membrane potential values
- The TI stimulation is now implemented in the current clamp

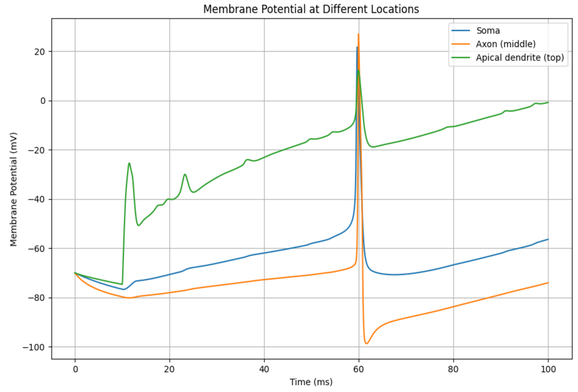
TI Results

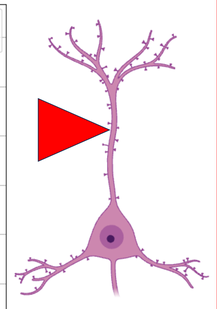


- *Top: TI signal applied to model. Bottom (left): Membrane potential of the model when TI is applied at soma. Bottom (right): When applied at top of apical tree.*









- With a 1 kHz carrier and a 10 Hz beat frequency for a zero-mean input, the model generates action potentials, supporting nonlinear integration of the TI field.
- This work suggests that neurons can be activated by focalized TI stimulation, and future modeling work will explore periodic entrainment of the neuronal activation to the TI beat frequency

References

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10539552/
[2] https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2022.918470/full
Model: https://modeldb.science/195615?tab=7

Acknowledgement

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