Hodgkin-Huxley framework-based associative memory for neural adaptation in the human temporal lobe

Diletta Bartolini | University of Pavia

A key role of the human brain is to adapt to novel situations by leveraging prior experiences. This adaptability manifests behaviorally as faster reaction times to repeated or similar stimuli, and neurophysiologically as reduced neural activity, which can be observed through bulk-tissue measurements like fMRI or EEG. Various single-neuron mechanisms have been proposed to account for this macroscopic reduction in activity. A study using human single-neuron recordings in chronic invasive epilepsy monitoring has recently investigated these mechanisms using visual stimuli with abstract semantic similarities within an adaptation paradigm.

We are developing a mathematical model to replicate these experimental results, designing an associative memory model based on a variant of the Hodgkin-Huxley framework with time-delayed couplings, capable of storing patterns in its synaptic weights.

Our model simulates key neuronal processes by incorporating Fast-Spiking neurons, essential for sensory information processing in the neocortex, and Regular-Spiking with Adaptation neurons, the predominant excitatory neurons in the cortex with adaptable firing patterns. These neurons are interconnected via either electrical or chemical synapses, as both coexist in all nervous systems. Each neuron receives inputs from multiple others, enabling complex network dynamics. Electrical synapse weights are fixed, while chemical synapse weights are chosen based on what the network is required to memorize.

Preliminary results suggest that a model consisting of only 300 neurons successfully reproduces behavioral priming, evidenced by reduced latency in reinstating a learned pattern. Future steps will focus on elucidating the underlying mechanisms that facilitate the reinstatement of firing patterns. Additionally, we aim to implement learning algorithms that enable the network to encode more meaningful stimulus representations and achieve accurate classification of stimuli.

Authors:

Diletta Bartolini
Department of Mathematics, University of Pavia, Pavia, Italy
Faculty of Mathematics and Computer Science, UniDistance Suisse, Brig, Switzerland

Thomas P. Reber
Faculty of Psychology, UniDistance Suisse, Brig, Switzerland
Department of Epileptology, University of Bonn Medical Centre, Bonn, Germany

Matthias Voigt
Faculty of Mathematics and Computer Science, UniDistance Suisse, Brig, Switzerland"