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Data-driven model of auditory thalamocortical system rhythms

We used the NEURON simulator with NetPyNE to develop a biophysically-detailed model of the macaque auditory thalamocortical system. We simulated a cortical column of 2000um depth and 200um diameter, with over 12k neurons and 30M synapses. Neuron types, densities, biophysics, and connectivity were derived from experimental data. We used the model to investigate the oscillatory patterns observed in electrophysiology data from awake, nonhuman primates in response to different classes of auditory stimuli.

The A1 model included 6 cortical layers with 4 excitatory cell populations (e.g. intratelencephalic, spiny stellate), and 4 inhibitory populations (e.g. somatostatin, neurogliaform). This A1 model was reciprocally connected to a biophysically-detailed thalamic model, which included medial geniculate body (MGB) and thalamic reticular nucleus (TRN).

Thalamic regions were driven by phenomenological models of the cochlear nerve and inferior colliculus, both of which captured the main signal transformations occurring in these structures. This software allowed us to input any arbitrary sound to the model, allowing us to match the stimuli presented to awake macaque monkeys with the stimuli presented to the model.

We used evolutionary optimization to tune the network to reproduce experimentally-constrained firing rates for each of the 42 neural populations. We tuned 12 high-level connectivity parameters, including background input and synaptic weight gains (E->E, E->I, I->E, I->I), within biologically plausible ranges. To the best of our knowledge, this is the first time evolutionary optimization was successfully used for large-scale biophysically-detailed network models.

By comparing in silico and in vivo responses to the same auditory stimuli, we are able to investigate the mechanistic origins of spatiotemporal oscillatory patterns observed in vivo. Model predictions will then be tested in vivo, using deep brain electrical microstimulation and pharmacological manipulations.