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2011

Preprint:

This is an accepted article published in Frontiers in Systems Neuroscience. Conference Abstract: Computational and Systems Neuroscience. The final authenticated version is available online at: https://doi.org/[DOI not available]

A simulation study on different STDP models concerning localized gamma oscillations

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Summary

Gamma oscillations are a prominent feature in experimental as well as theoretical descriptions of brain activity. One of the network models which has the capability to generate such oscillations is what we call a local cell assembly (CA), i.e. a group of neigbouring neurons which are strongly interconnected in an excitatory manner. Postulated by experimenters and extensively used in theoretical studies, these local networks seem to be a good candidate for investigating the impact of biological constraints given by models of spike-timing-dependent plasticity (STDP) on local gamma oscillating structures in the mammalian brain.

Therefore we fitted a two-compartment neuron model with AMPA- and NMDA-receptor mediated synaptic currents to desired properties of a local CA, meaning pattern completion and after-activity. We simulated 100 recurrently connected neurons with fixed axonal transmission delays. In addition, every neuron receives Poissonian spikes from 1000 input cells firing at low background rate ν. During simulation the network is stimulated every second by increasing the input rate to 10ν for 35 msec. As a quality measure for keeping or even enhancing the properties of the network, we counted the relative amount of synapses with increased synaptic strengths with reference to the initial values. Three phenomenological STDP models (Song et al., Nature Neuroscience, 3, 2000; Pfister and Gerstner, The J. of Neuroscience, 26, 2006; Clopath et al., Nature Neuroscience, 13, 2010) were implemented. Model-specific parameters were varyied in ranges determined by experimental measurements.

We conclude that more recent STDP models which take into account frequency-dependent terms lead to a higher probability of strengthening synapses in a local CA (larger LTP region). This corresponds to experimental observations that long-term potentiation (LTP) outweighs long-term depression (LTD) in high-frequency pairing protocols. Furthermore our simulations show that short axonal transmission delays clearly enlarge the LTP region of STDP parameter space.