Emergence of Oriented Circuits driven by Synaptic Pruning associated with Spike-Timing-Dependent Plasticity (STDP)

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Massive synaptic pruning following over-growth is a general feature of mammalian brain maturation. Pruning starts near time of birth and is completed by time of sexual maturation. Trigger signals able to induce synaptic pruning could be related to dynamic functions that depend on the timing of action potentials. Spike-timing-dependent synaptic plasticity (STDP) is a change in the synaptic strength based on the ordering of pre– and postsynaptic spikes. The relation between synaptic efficacy and synaptic pruning suggests that the weak synapses may be modified and removed through competitive "learning" rules. This plasticity rule might produce the strengthening of the connections among neurons that belong to cell assemblies characterized by recurrent patterns of firing. Conversely, the connections that are not recurrently activated might decrease in efficiency and eventually be eliminated.

The main goal of our study is to determine whether or not, and under which conditions, such cell assemblies may emerge out of a locally connected random network of integrate-and-fire units distributed on a 2D lattice receiving background noise and content-related input organized in both temporal and spatial dimensions. The originality of our study stands on the relatively large size of the network, 10,000 units, the duration of the experiment, 10^6 time units (one time unit corresponding to the duration of a spike), and the application of an original bio-inspired STDP modification rule compatible with hardware implementation.

A first batch of experiments was performed to test that the randomly generated connectivity and the STDP-driven pruning did not show any spurious bias in absence of stimulation. Among other things, a scale factor was approximated to compensate for the network size on the activity. Networks were then stimulated with the spatiotemporal patterns. The analysis of the connections remaining at the end of the simulations, as well as the analysis of the time series resulting from the interconnected units activity, suggest that feed-forward circuits emerge from the initially randomly connected networks by pruning.