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Capacity of networks to develop multiple attractors through STDP

Amelia Waddington*[1] and Netta Cohen[1,2]

Address: [1]School of Computing, University of Leeds, Leeds, West Yorkshire LS7 4SS, UK and [2]Institute of Systems and Membrane Biology, University of Leeds, Leeds, West Yorkshire LS7 4SS, UK

Email: Amelia Waddington* - amelia@comp.leeds.ac.uk

* Corresponding author

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Biological neural networks display much variation in form and structure, each specialized for the information-processing task at hand. It has been shown in many cases that the immature network must be exposed to the correct neural activity in order for the appropriate structure to develop. Understanding how early activity patterns determine network structure is a major question in developmental neuroscience today.

There are many plasticity mechanisms that are known to be activity dependent: neural growth, pruning, synaptogenesis, synaptic plasticity, modifications of membrane properties and neurotransmitter expression. We focus on synaptic plasticity, specifically, spike-timing-dependent plasticity (STDP). Experimental studies have found that STDP is present in developing systems [1,2] and theoretical studies have shown that STDP is able to guide structural changes analogous to those seen in developing networks [3-5].

Networks with layered structures, each layer projecting forward onto the next, are able to produce precisely timed sequences of spikes. This type of structure is known as a synfire chain [6-8]. Theoretical studies have shown that an initially recurrent network of artificial neurons subjected to a repeating input can develop into a network with a layered structure when synapses are modified according to STDP [9-11].

Here we investigate how this previously proposed synfire development mechanism generalizes to systems with multiple inputs. We study a recurrent network consisting of a population of excitatory leaky integrate and fire neurons with background spontaneous activity and global inhibition. We demonstrate that when subjected to distinct inputs and STDP, such networks develop distinct synfire chains that respond to each input, reflecting the existence of multiple attractor states. We analyze the capacity of networks, addressing how the number of attractors and their properties scale. We also examine how the capacity of the network is related to the degree of overlap in the neuronal activity (between different synfire chains).

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