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Dopamine modulated dynamical changes in recurrent networks with short term plasticity

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Dopamine is commonly considered as reward signal [1] and also as punishment signal [2] and is tightly coupled with memory and learning processes. In computational models, learning is simulated often on synapses by spike-timing-dependent plasticity (STDP), which depends on fine-timescale relationships between pre and postsynaptic spikes. However, most neocortical synapses exhibit also a mixture of depression and facilitation in a short time scale of few hundred milliseconds, which is referred as short-term plasticity [3,4]. The short-term plasticity stabilizes the network activity and changes dramatically the network dynamics, up to evidences of behavior dependency [5].

In our modeling study, we investigate the dynamic changes in a recurrent, spiking neural network model at different dopamine levels and its interaction with the short-term plasticity. The network consists of excitatory and inhibitory biologically plausible neurons [6]. The network was established by local and long-range (displaced) connections [7] with $GABA_A$, $GABA_B$, NMDA and AMPA synapses. The synaptic efficiency (short-term plasticity) is modeled with the phenomenological model in [8]. The values and statistical distributions are taken from [8,9]. The influence of dopamine is approximated by up and down regulating of the maximal conductance of the $GABA_A$ and NMDA synapses on excitatory cells in same direction [10-12].

We analyze STDP relevant events (pairs of pre- and postsynaptic spikes) in a range of -20...+20 ms on each synapse and found a clear dependency on dopamine level. Up regulating the conductance increases the number of such events and changes the distribution of the time differences. We demonstrate the effects of dopamine over a large variation of initial synaptic weights and stimulation patterns.

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