BMC Neuroscience

BioMed Central

Poster presentation

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Dopamine mediated dynamical changes in the striatum: a numerical study

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from Eighteenth Annual Computational Neuroscience Meeting: CNS*2009
Berlin, Germany. 18–23 July 2009

Published: 13 July 2009

BMC Neuroscience 2009, **10**(Suppl 1):P150 doi:10.1186/1471-2202-10-S1-P150

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P150

The striatum is a part of the basal ganglia, which are a group of nuclei in the brain associated with motor control, cognition and learning. In this study we examined the consequences of the dopamine modulation in a small striatal network. We employed point neuron models to analyze the conductance based dopaminergic changes. The model is built from the following elements: tonically active neuron (cholinergic interneuron) (TAN), dopaminergic neuron (DAN), medium spiny neuron (MSN) and fast spiking interneuron (FSN). TANs are are able to fire in the absence of synaptic inputs and respond to sensory stimuli and sensorimotor learning by transiently suppressing their firing activity [1]. This pause is dopamine signal sensitive, but the neurophysiological mechanism of the dopaminergic influence is under debate. We analyzed the robustness of the TAN subthreshold oscillations and demonstrated how they are affected by dopaminergic modulation [1]. The TAN-DAN interaction is reciprocal and precisely timed [2]. TAN pause responses co-occur with the DAN bursts and both influence the activities of the MSN neurons and the feed-forward FSN neurons. Our aim was to examine the dynamic interactions in this network and study the effects of the dopaminergic/cholinergic time-dependent modulations [3].

Our results predict that the dopamine mediated effects (through D1 and D2 receptors) are able to switch the TANs between stable oscillatory and fixed-point behaviors [1]. The results suggest that the MSN neurons exhibit dynamical sub-threshold hysteresis without showing static hysteresis and this bi-stability is dopamine dependent [4]. We further predict that different dopamine receptors (D(1) and D(2)) mediate opposing dynamical effects on these cell types (small network) and we suggest that these opposing effects act on different timescales.

Our work seeks to more deeply understand the details of the striatal small network dynamics and give predictions for the possible dynamical consequences of the dopamine depleted states, where the cortico-striatal coupling is weakened and the striatal firing thresholds are reduced [5,6].

We thank to Peter Simon for his help and useful discussions. KSz was supported by the Eötvös Fellowship. This work was further supported by the EU Sixth Framework programme grant no.: IST-4-027819-IP, ICEA).

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