Safaryan et al. BMC Neuroscience 2010, 11(Suppl 1):P118
http://www.biomedcentral.com/1471-2202/11/S1/P118

BMC Neuroscience

POSTER PRESENTATION | Open Access

The effect of non-specific LTD on pattern recognition in cerebellar Purkinje cells

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From Nineteenth Annual Computational Neuroscience Meeting: CNS*2010
San Antonio, TX, USA. 24-30 July 2010

Long-term depression (LTD) of synapses between parallel fibres (PFs) and Purkinje cells in the cerebellar cortex has been suggested as mechanism for cerebellar learning and pattern recognition [1]. PF LTD can be induced by coincident PF and climbing fibre (CF) input to Purkinje cells, and existing theories of cerebellar learning assume that LTD is specific to the PF synapses that are activated when a CF signal is presented [2]. However, experimental evidence indicates that this view is too simplified. When PF LTD is induced by pairing PF input with Purkinje cell depolarization that mimics the effect of CF input, a non-specific form of PF LTD also develops that spreads to neighbouring synapses [3]. The amount of this non-specific LTD decreases with distance from the stimulated PF synapses in 3D.

As many learning theories in neural networks assume that pattern recognition is implemented by specific weight changes at individual storage sites, non-specific LTD is expected to result in a decreased performance. A degradation of performance based on non-specific plasticity has recently been shown for an unsupervised learning task using Oja's rule [4]. Here we study the effect of non-specific LTD in a simple artificial neural network (ANN) with a LTD based learning rule. We store a number of input patterns in the ANN and compare its performance in the absence and presence of non-specific LTD with varying spatial spreads. The performance of the ANN is evaluated by measuring its responses to the stored patterns and an equal number of novel patterns. The ability to discriminate between stored and novel patterns is quantified by calculating a signal-to-noise ratio [5]. Not surprisingly, non-specific LTD results in loss of performance.

However, when the ANN is presented with stored patterns that have been degraded by adding different amounts of spatial noise, implemented by shifting active inputs to neighbouring locations, the effect of the non-specific LTD is reversed. While the performance of an ANN without any non-specific LTD drops dramatically in the presence of spatial noise in the input patterns, the presence of non-specific LTD introduces robustness against spatial noise. This effect is particularly pronounced when the spatial spread of the LTD is matched with the spatial spread of the noise in the input patterns. Our results suggest a potential computational role for non-specific LTD in Purkinje cells. We are currently studying non-specific LTD in simulations of a multi-compartmental conductance-based Purkinje cell model [6].

Published: 20 July 2010

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doi:10.1186/1471-2202-11-S1-P118
Cite this article as: Safaryan *et al.*: The effect of non-specific LTD on pattern recognition in cerebellar Purkinje cells. *BMC Neuroscience* 2010 **11**(Suppl 1):P118.

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