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Decoding of Purkinje cell pauses by deep cerebellar nucleus neurons

Johannes Luthman*, Rod Adams, Neil Davey, Reinoud Maex and Volker Steuber

Address: Science and Technology Research Institute, University of Herfordshire, Hatfield, AL10 9AB, UK

Email: Johannes Luthman* - J.Luthman@herts.ac.uk

* Corresponding author

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The recognition of parallel fibre (PF) input patterns by Purkinje cells has been suggested to underlie cerebellar learning [1,2]. A candidate mechanism for the recognition of PF patterns is the long-term depression (LTD) of the PF synapses that is induced when the Purkinje cell receives coincident PF and climbing fibre input [3].

Recent work has shown that Purkinje cells can read out PF patterns that have been stored by PF LTD by using a novel neural code [4]. Computer simulations and electrophysiological recordings in slices and awake mice predicted that the presentation of patterns of synchronised PF activity results in a characteristic burst-pause sequence in Purkinje cell firing, with novel patterns giving rise to longer pauses than stored patterns. The duration of these pauses was the best criterion to distinguish Purkinje cell responses to stored and novel patterns.

In the present study, we used a two-layer network model to investigate the effect of PF LTD on the target neurons of the Purkinje cells in the deep cerebellar nuclei (DCN). In our simulations, a multi-compartmental conductance-based DCN model [5] received input from up to 450 independent Purkinje cell models through inhibitory GABAergic synapses. PF patterns were stored by depressing the synapses between the PFs and the Purkinje cells. The network was presented with stored and novel PF patterns, and the ability of the DCN model to distinguish between those was evaluated by calculating signal-to-noise ratios for different features of its spike response. The simulations were performed for different Purkinje cell firing rates and for varying fractions of Purkinje cells that received PF input patterns.

The presentation of PF patterns to the network resulted in the burst-pause response in the Purkinje cells that had previously been described [4]. These burst-pause sequences caused a characteristic spike response in the DCN model, comprising a short pause that was followed by a rebound burst and another pause. Several features of this DCN response could be used to identify stored PF patterns, but the number of spikes in the rebound burst was clearly the best criterion for pattern recognition. The pattern recognition performance was amplified by the DCN model, with signal-to-noise ratios that were up to seven times higher than those measured for the Purkinje cell response. Our results are robust against varying Purkinje cell firing rates and to a five-fold reduction of the number of Purkinje cells receiving PF input patterns.

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