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Computational prediction for brainstem plasticity in vestibulo-ocular reflex

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Abstract:
The accuracy of the horizontal VOR is maintained by adaptive processes that utilise both cerebellar cortex and brainstem sites of plasticity (e.g. Lisberger 1998). We have presented elsewhere (Dean & Porrill 2004) a computational analysis showing that a second site of plasticity is needed to avoid potential instabilities in adapting high frequency VOR gain when the retinal slip teaching signal is delayed.
This analysis suggests a cortex-first learning rule in which learning at the cerebellar site of plasticity occurs first and the subsequent modulation of cerebellar output drives brainstem adaptation, selectively transferring cerebellar gain to the brainstem. This mechanism predicts that:(i) both sites require an intact cerebellum during learning; (ii) when learning is complete, changes in brainstem gain can be expressed despite cerebellar inactivation; (iii) plasticity of the intrinsic properties of brainstem neurons could mediate the changes in gain needed for plant compensation.
Here we investigate in more detail the predictions of the cortex-first mechanism for the nature of the plasticity at the inhibitory synapses of floccular Purkinje cells onto the floccular target neurons in the medial vestibular nucleus (MVN) (a mechanism based on changes in intrinsic excitability is also possible but is not investigated here). We construct a mechanistic spike timing dependent plasticity rule that has the required behavioural properties and show that this rule predicts LTD when IPSCs from floccular target neurons are closely correlated in time with EPSCs from vestibular inputs.
This prediction is unexpected in view of recent results for the deep cerebellar nuclei (DCN) which contain the target neurons for cerebellar cortical output in other motor systems (Pugh & Raman 2006). There it was found that correlating excitatory synaptic inputs with post-synaptic hyperpolarisation simulating cerebellar inhibition lead to LTP rather than LTD. Given the similarities between the roles of MVN and DCN this difference in sign is surprising and indicates the importance of investigating the learning rules that govern plasticity in the MVN.
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