Contingency learning by an adaptive filter model of the cerebellum in simulated eyeblink conditioning

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Eyeblink conditioning (EBC) is a cerebellum-dependent form of associative learning, and specific computational models have simulated several of its characteristics. Here, however, we describe how a generic, adaptive filter version of the Marr-Albus model of the cerebellum can be applied to EBC. Successful use of this model in motor-control problems, such as calibration of the vestibulo-ocular reflex (Dean, Porrill & Stone 2002), requires that system output affects the error signal. However, in EBC the conditioned response (CR) cannot affect the unconditioned stimulus (US), so that the US alone as an error signal would not give a stable end-point to learning. One solution proposed for EBC is that inhibitory neurons in the anterior interpositus nucleus send a copy of the CR command to the inferior olive (IO). The resultant gating of the US signal (Andersson, Garwicz & Hesslow 1988) effectively compares the CR and US to reduce the error signal as conditioning is acquired. Here we examine whether this error signal could generate contingency learning with multiple conditioned stimuli (CSs).

The model architecture consisted of a non-adaptive brainstem pathway in parallel with an adaptive cerebellar pathway, converging on the premotor nuclei of the eyelid plant (Lepora et al 2007, Lepora et al 2009). US input to the brainstem drove the unconditioned response (UR), while CS inputs via the cerebellum drove the CR. The IO compared copies of the US and CR command to form a climbing fibre error signal. This error signal drove learning in an adaptive filter model of the cerebellum with a covariance learning rule. All quantities were real-time signals. Trial-level features were then extracted.

For a single CS, the model exhibited acquisition and extinction behaviour with realistic response profiles. For multiple CSs, the model also exhibited blocking, overshadowing (as a function of CS salience) and conditioned inhibition effects. Trial-level results were very similar to those in Rescorla-Wagner type trial-level models. Learning curves depended on the IO comparator; modelling nucleo-olivary inhibition as signal subtraction led to those of the Rescorla-Wagner model.

The results suggest that the adaptive filter model of the cerebellum can be applied to both prediction and motor control. It can thus provide a unified framework which allows systematic investigation of key theoretical features of classical conditioning, such as CR timing, in relation to adaptive-filter structure. However, it is currently unclear how the error signal investigated here could be combined with a signed positional error proposed for UR adaptation by the cerebellum (c.f. SFN poster by Dean et al. 2007).

The work in this abstract has been published in (Lepora et al 2010).

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