Simple recruitment model describes control of conditioned nictitating membrane responses by retractor bulbi muscle

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Cerebellar control of conditioned eyeblink response dynamics is not well understood. Previous modelling of the signal sent from the anterior interpositus nucleus (via the red nucleus) to the accessory abducens nucleus suggested that this signal is linearly related to desired muscle force, because appropriate recruitment within the motoneuron (MN) pool linearised the dynamics of the nictitating membrane (NM) response (Lepora et al 2005). Here we extend the analysis to investigate possible recruitment mechanisms.

Data came from simultaneous recordings of NM position and multi-unit electromyographic (EMG) activity from the retractor bulbi muscle of subjects during eyeblink conditioning with a tone as conditioned stimulus and periocular stimulation as unconditioned stimulus. Putative action potentials (spikes) were extracted from EMG records, and classified according to height. The relationships between spike trains of different heights and inferred input signals were then analysed.

The main findings were that (i) spikes only appeared when the input signal was above a certain threshold, that was linearly related to spike height; (ii) spike frequency during a conditioned response had an approximately Gaussian profile; (iii) the width of the Gaussian declined linearly with spike height; and (iv) firing frequency declined exponentially with spike height. All these findings could be reproduced by a simple recruitment model in which each MN receives the same input signal (common drive), and has the same slope relating above-threshold input to frequency of firing. MN thresholds themselves are spaced exponentially with respect to input current, and are linearly related to spike height. Initial investigation suggests that such a pattern of MN firing produces nonlinear increases in isometric force with input signal, in a manner that offsets the effects of muscle shortening at large NM response amplitudes.

This EMG-based recruitment model thus proposes a mechanism that enables the cerebellar output signal to be linearly related to response topography. In addition, it is similar to the model proposed by Senn et al (1997) for minimising expected force in skeletal muscle, suggesting that the organisation found here for the retractor bulbi muscle may be of general significance.

The work in this abstract has been published in (Lepora et al 2007, Lepora et al 2009, Mavritsaki et al 2007).

References

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