Evidence for Linearity in Control of Nictitating Membrane Responses by Retractor Bulbi Motor Units

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In analyses of cerebellar function in eyeblink conditioning, conditioned response (CR) topography is often assumed to be identical to the frequency profile of neuronal firing in the interpositus nucleus (e.g. Medina & Mauk 2000). However, in a detailed model of nictitating membrane (NM) response production by the retractor bulbi (RB) muscle, the force exerted by an individual motor unit is a sigmoidal function of motoneuron (MN) frequency with only a small linear range (Bartha & Thompson 1992, based on measurements by Lennerstrand 1974).

We investigated this apparent discrepancy by simultaneously recording NM position and multi-unit electromyographic (EMG) activity from the RB muscle of rabbits during conditioning using with tone CS and periocular shock US. Spikes were extracted from EMG records, and a linear filter applied to the resultant spike trains to generate the corresponding CR profiles. The best fit filters were estimated using standard least-squares procedures.

In 4 subjects the CR profiles (amplitudes up to 7 mm) could be well approximated by first order filters with decay time constants ~250 ms. Hence, although CR profiles cannot be derived by application of a simple gain term to MN firing-frequencies, they can be modelled by a linear system whose time constants primarily reflect the viscosity and elasticity of the orbital tissue and Harder's gland. This observed linearity is consistent with the non-linear model of Bartha and Thompson only if CR amplitude is controlled by recruitment of new motor units, rather than by changes in firing frequency of units already recruited (Mavritsaki et al 2007). The observed presence of larger amplitude EMG spikes for larger CRs is consistent with the recruitment of new motor units (Sanders 1996).

The linearity of the system may be important for making CRs easier to control by higher levels of the motor system.

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

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