The Neural Code for Motor Control in the Cerebellum and Oculomotor Brainstem.

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Abstract:

A single extra spike makes a difference. Here, the size of the eye velocity in the initiation of smooth eye movements in the right panel depends on whether a cerebellar Purkinje cell discharges 3 (red), 4 (green), 5 (blue), or 6 (black) spikes in the 40-ms window indicated by the gray shading in the rasters on the left. Spike trains are rich in information that can be extracted to guide behaviors at millisecond time resolution or across longer time intervals. In sensory systems, the information usually is defined with respect to the stimulus. Especially in motor systems, however, it is equally critical to understand how spike trains predict behavior. Thus, our goal was to compare systematically spike trains in the oculomotor system with eye movement behavior on single movements. We analyzed the discharge of Purkinje cells in the floccular complex of the cerebellum, floccular target neurons in the brainstem, other vestibular neurons, and abducens neurons. We find that an extra spike in a brief analysis window predicts a substantial fraction of the trial-by-trial variation in the initiation of smooth pursuit eye movements. For Purkinje cells, a single extra spike in a 40 ms analysis window predicts, on average, 0.5 SDs of the variation in behavior. An optimal linear estimator predicts behavioral variation slightly better than do spike counts in brief windows. Simulations reveal that the ability of single spikes to predict a fraction of behavior also emerges from model spike trains that have the same statistics as the real spike trains, as long as they are driven by shared sensory inputs. We think that the shared sensory estimates in their inputs create correlations in neural spiking across time and across each population. As a result, one or a small number of spikes in a brief time interval can predict a substantial fraction of behavioral variation.

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