Dynamic synapses as timers for temporal coding and learning

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Abstract

Task repetition and practice can be used to learn precise and rapid sensorimotor and cognitive behaviors, for which the brain must detect and predict the passage of time. How neurons within neural circuits can represent or "compute" time is not known. The cerebellar cortex is thought to use a largely feed-forward circuit to generate distributed representation of time in cerebellar granule cells (temporal basis), which allows associated learning mechanisms to precisely teach or guide output neurons, Purkinje cells (PCs), to generate any output pattern necessary for controlling behavior. However, the mechanisms by which this is achieved is unknown. We discovered that synapses at the input layer of the cerebellar cortex are functionally diverse (in strength and short-term plasticity) and tuned to the information (input pathway) that they transmit. We hypothesize that the diversity of synaptic dynamics is necessary for generating a temporal basis in GCs. We tested this using a rate-model of the cerebellar cortical circuit, and show that indeed the diversity of short-term dynamics can generate diverse GC firing patterns that are sufficient to learn the delayed eye-lid conditioning task. We propose that synaptic STP is a substrate for neural circuit timing sufficient to drive temporally precise behaviors.

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