Abstract View

CEREBELLAR GLOMERULI: DOES LIMITED EXTRACELLULAR CALCIUM DIRECT A NEW KIND OF PLASTICITY?

O.J.-M. Coenen*; D.M. Eagleman; V. Mitsner; T.M. Bartol; A.J. Bell; T.J. Sejnowski

CNL, Salk Institute, La Jolla, CA, USA

A class of synaptic learning models, in which a sum of postsynaptic activity from many neurons drives plasticity, has generally been considered biologically infeasible. After all, postsynaptic cell bodies may be far apart, and there are no backward signals known to sum activity in a terminal-specific manner. However, some specialized synapses, known as glomeruli, become ensheathed by glial cells, and we suggest that these structures may allow for just such a postsynaptic summation. The ensheathment may force enclosed, neighboring dendrites to share a limited resource: extracellular calcium (ECa). We propose the theory that the ECa concentration in glomeruli may encode the level of spike activity in postsynaptic cells. We investigate here cerebellar glomeruli, where dendrites from granule cells swirl around a mossy fiber terminal, and the ensemble is tightly ensheathed in an astrocyte. Computer analyses of 3D simulated glomeruli, with realistic channel kinetics and Monte Carlo modeling of calcium diffusion using MCell, indicate the range of conditions under which ECa will be proportional to the sum of granule cell activity. We also show how these ECa changes can be interpreted from an information-processing point of view, generating a novel learning rule for control of plasticity at the mossy fiber/granule cell synapse. This learning rule approaches a sparsely distributed and statistically independent coding in the parallel fibers. Although traditional neural models emphasize only neurotransmitters and connectivity, these results highlight the need to quantitatively address the 3D context in which axons and dendrites are found.

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