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Learning from unexpected events in the neocortical microcircuit

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Predictive learning hypotheses posit that the neocortex learns a hierarchical model of the structure of features in the environment. Under these hypotheses, expected or predictable features are differentiated from unexpected ones by comparing bottom-up and top-down streams of data, with unexpected features then driving changes in the representation of incoming stimuli. This is supported by numerous studies in early sensory cortices showing that pyramidal neurons respond particularly strongly to unexpected stimulus events. However, it remains unknown how their responses govern subsequent changes in stimulus representations, and thus, govern learning. Here, I present results from our study of layer 2/3 and layer 5 pyramidal neurons imaged in primary visual cortex of awake, behaving mice using two-photon calcium microscopy at both the somatic and distal apical planes. Our data reveals that individual neurons and distal apical dendrites show distinct, but predictable changes in unexpected event responses when tracked over several days. Considering existing evidence that bottom-up information is primarily targeted to somata, with distal apical dendrites receiving the bulk of top-down inputs, our findings corroborate hypothesized complementary roles for these two neuronal compartments in hierarchical computing. Altogether, our work provides novel evidence that the neocortex indeed instantiates a predictive hierarchical model in which unexpected events drive learning.

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