

Title:

Identifying plasticity mechanisms underlying context-dependent neural responses in cortical circuits

Summary:

Biological circuits rapidly adapt to sensory stimuli through experience and ongoing learning in a non-trivial manner. Extensive experimental evidence indicates that neural circuits operate in distinct processing modes based on contextual information characterised by differential responses to the same stimuli. In early sensory cortices, different neuronal subtypes are thought to have specialized functional roles in controlling sensory information flow through the cortical hierarchy. Specifically, in mouse primary visual cortex (V1), populations of pyramidal and vasoactive-intestinal-peptide-expressing (VIP) cells show pronounced responses to novel and unexpected visual stimuli, while they rapidly adapt to elicit moderate responses to familiar or expected ones. However, the exact plasticity and circuit mechanisms that establish these distinct responses are not fully characterised.

Here, we analysed electrophysiological recordings from visual cortex and adjacent visual areas of mice performing a sequential visual discrimination task that establishes contextual stimulus expectations. Our analyses identified distinct inter-area communication patterns based on stimulus condition, suggesting selective, context-driven information routing to V1. To characterise the circuit design constraints and synaptic plasticity mechanisms that explain our empirical findings, we developed a data-constrained recurrent neural network model with three inhibitory interneuron subtypes. Using linear response theory on a mean-field approximation of the model, we derived the necessary circuit conditions on population interactions to replicate the experimentally observed responses. Our work provides a mechanistic explanation of how cortical circuits adjust their activity in response to contextual cues and stimulus expectations.

