Comparing roles of feedback and feedforward inhibition in sparsening of sensory codes

Pavel Sanda[1], Tiffany Kee[1], Nitin Gupta[2], Mark Stopfer[2], Maxim Bazhenov[1]

1. University of California, Riverside, CA; 2. NIH–NICHD, Bethesda, MD

Abstract

Sparse sensory codes offer several advantages, particularly in the context of associative learning. Kenyon cells of the mushroom body (MB), an area of the insect brain thought to be involved in olfactory learning, show remarkably sparse responses: a given odor elicits very few action potentials, from very few cells. KCs receive excitatory input from the projection neurons (PNs) of the antennal lobe (AL). PNs also project to another area of the brain, the lateral horn (LH). In locusts, feedforward inhibition from the LH to the KCs was thought to maintain the sparseness of KC responses across a wide range of odor concentrations. New experimental evidence, however, shows that the primary source of inhibition to KCs is a giant GABAergic neuron (GGN). KCs provide excitatory input to GGN, which, in turn, inhibits the KCs, forming a negative feedback circuit that could also regulate the sparseness of KCs. To examine whether the feedback inhibition would have different functional properties compared to the feedforward inhibition, we devised a network model of the locust olfactory system, including local neurons of the AL, PNs, KCs and GGN. The properties of GGN and other neurons in the model were tightly constrained by in vivo experimental data. We simulated two variants of the model, with feedforward or feedback inhibition to the KCs. We found that both feedforward and feedback models could maintain the sparse responses of KCs across a range of odor concentrations and provide phase-locking of spikes with the local field potential, as observed experimentally. The feedback model, however, produced a more stable discrimination of odors than the feedforward model. The feedback model reached optimal classification within 300 ms of stimulus presentation, consistent with the experimental observations. Our results illuminate the conditions in which feedback inhibition is advantageous for maintaining sparse sensory responses.