Feedforward vs. feedback inhibition to regulate the sparse firing of olfactory neurons

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The mushroom body (MB) of the locust (Schistocerca americana) contains Kenyon cells (KCs) which respond to odors very specifically and very sparsely; that is, a given odor elicits very few action potentials from very few cells. We previously proposed that feedforward inhibition from lateral horn (LH) interneurons to the KCs helps maintain the sparseness of the responses of KCs across a wide range of odor concentrations. However, new experimental evidence suggests that feedback inhibition mediated by another cell, the giant GABAergic neuron (GGN), is used by the locust olfactory system to maintain sparse but varied excitation in the KCs. The circuit starts with excitatory input from the projection neurons (PNs) of the antennal lobe (AL) activating the KCs. The KCs then directly excite GGN which, in turn, directly inhibits the KCs, forming a negative feedback circuit. To examine whether the current hypothesized feedback system would have different functional properties than the previously hypothesized feedforward model we designed a new network model of the locust olfactory system that includes PN and local neurons of the AL, KCs and GGN. The model of GGN was designed to match closely experimental response properties recorded in vivo from the locust. Two models were compared: 1) the feedback model included excitatory projections from KCs to GGN; 2) the feedforward model included excitatory projections from PNs to GGN. We found that both models could maintain the sparse responses of the KCs across a range of odor concentrations. However, only the feedback model reproduced the experimentally observed slower (than LFP) frequency of GGN oscillations. The feedback model also generated responses in KCs for different odors that were more different from each other than responses generated by the feedforward model. Results from recent physiology experiments suggest feedforward connections from PNs to GGN may not exist in the locust. Our modeling results are consistent with this view, and illuminate a potential benefit of feedback organization.

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