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Sequential sparsing by successive adapting neural populations

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In the principal cells of the insect mushroom body, the Kenyon cells (KC), olfactory information is represented by a spatially and temporally sparse code. Each odor stimulus will activate only a small portion of neurons (spatial sparseness) and each stimulus leads to only a short phasic response following stimulus onset (temporal or lifetime sparseness) irrespective of the actual duration of a constant stimulus. The mechanisms responsible for the temporally sparse code in the KCs are yet unresolved.

Here, we explore the role of the neuron-intrinsic mechanism of spike frequency adaptation (SFA) in producing temporally sparse responses to sensory stimulation in higher processing stages. SFA is an ubiquitous phenomena found in many different model systems. Our single neuron model is defined through a full five-dimensional master equation for a conductance-based integrate-and-fire neuron with spike-frequency adaptation [1]. We study a fully connected feed-forward network architecture in coarse analogy to the insect olfactory pathway. A first layer of ten neurons represents the projection neurons (PNs) of the antenna lobe. All PNs receive a step-like input from the olfactory receptor neurons, which was realized by independent Poisson processes. The second layer represents 100 KCs which converge onto ten neurons in the output layer which represents the population of mushroom body extrinsic neurons (ENs). Figure 1.

Our simulation result matches well with the experimental observations. In particular, intracellular recordings of PNs show a clear phasic-tonic response that outlasts the stimulus [2] while extracellular recordings from KCs in the locust express sharp transient responses [3]. We conclude that the neuron-intrinsic SFA mechanism is sufficient to explain a progressive temporal response sparsening in the insect olfactory system. Further experimental work is needed to test this hypothesis empirically.

References

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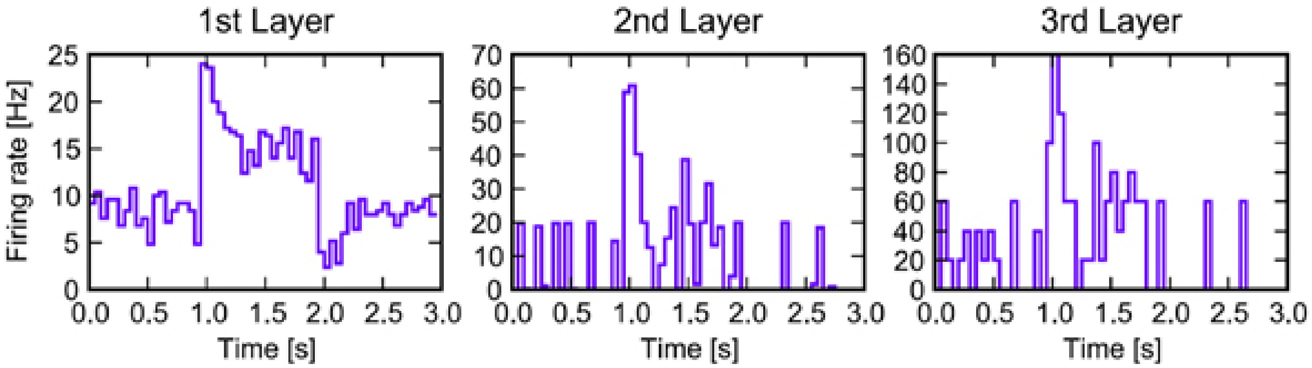

Figure 1

Layer-specific population response in a simplified feed-forward network of the insect olfactory pathway. Average population response in the first layer (left) to a step-like Poisson input shows a phasic-tonic response as observed in antennal lobe projection neurons. In the second layer (middle) the population response profile is dominated by a sharp onset transient and tonic firing is diminished. The final output layer (right) with reduced adaptation current integrates convergent input.