Learning synaptic properties from neural activity in a recurrent neural network model of insect olfaction

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Abstract

A key part of insect olfactory processing is the recurrent computation occurring in the antennal lobe (AL), where complex interactions between excitatory projection neurons (PNs) and inhibitory local neurons (LNs) shape odor representations. To elucidate the underlying mechanisms of olfactory coding, we developed a biologically constrained continuous rate recurrent neural network (RNN) model of the locust AL, trained to reconstruct in vivo electrophysiological data. Our model, comprising 830 PNs and 300 LNs, accurately captured the temporal dynamics and diverse response patterns of AL neurons. The trained network revealed sparse connectivity with differential connection densities between excitatory and inhibitory neuron populations, and no connections between excitatory neurons, consistent with empirical observations. Learned time constants predicted slower LN dynamics and diverse PN response patterns, with low and high time constants corresponding to early and late odor-evoked activity as reported in vivo. This approach demonstrates the utility of data-driven RNN models in inferring circuit properties and uncovering key mechanisms of odor representation in the insect AL, offering insights beyond traditional hand-tuned computational models.