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Session PSTR341 - Olfaction: Higher-Order Circuits

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PSTR341.04 / E32 - Hierarchical Learning and Denoising with an Olfaction-Inspired Neuromorphic Network

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Presenter at Poster
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Abstract
The goal of odor source separation and identification from real-world data presents a challenging problem. Both individual odors of potential interest and multisource odor scenes constitute linear combinations of analytes present at different concentrations. The mixing of these analytes can exert nonlinear and even nonmonotonic effects on cross-responsive chemosensors, effectively occluding diagnostic activity patterns across the array. Neuromorphic algorithms, inspired by specific computational strategies of the mammalian olfactory system, have been trained to rapidly learn and reconstruct arbitrary odor source signatures in the presence of background interference. However, such networks perform best when tuned to the statistics of well-behaved inputs, normalized and predictable in their activity distributions. Deployment of chemosensor arrays in the wild exposes these networks to disruptive effects that exceed these tolerances. To address the problems inherent to chemosensory signal conditioning and representation learning, the olfactory bulb deploys an array of strategies: (1) shunting inhibition in the glomerular layer implements divisive normalization, contributing to concentration-invariant representations; (2) feedforward gain diversification (synaptic weight heterogeneity) regularizes spiking activity in the external plexiform layer (mitral and granule cells), enabling the network to handle unregulated inputs; (3) gamma-band oscillations segment activity into packets, enabling a spike phase code and iterative denoising; (4) excitatory and inhibitory spike timing dependent learning rules induce hierarchical attraction basins, enabling the network to map its highly complex inputs to regions of a lower dimensional manifold; (5) neurogenesis in the granule cell layer enables lifelong learning and prevents order effects (regularizing the learned synaptic weight distribution over the span of training). Here, we integrate these motifs into a single neuromorphic model, bringing together prior OB-inspired model architectures. In a series of simulation experiments including real-world data from a chemosensor array, we demonstrate the network's ability to learn and

detect complex odorants in variable environments despite unpredictable noise distributions.