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Neuronal connectivity and computations in olfaction

Rainer Friedrich

Friedrich Miescher Institute for Biomedical Research, Basel, Switzerland

Odors are detected by sensory neurons in the nose expressing one out of many odorant receptors. Each odor activates a specific combination of receptors. Information about odors is therefore represented by distributed patterns of activity across an array of sensory input channels to the brain. The olfactory bulb (OB) is the first olfactory processing center in the brain and transforms odor-evoked sensory inputs from the nose into spatio-temporal output patterns that are transmitted by OB output neurons, the mitral cells, to multiple higher brain areas including memory centers. Chemically related odors evoke similar patterns of sensory input activity that are transformed in the OB into decorrelated and normalized patterns of activity across mitral cells. This transformation can be described as a whitening of activity patterns, which is thought to be fundamentally important for pattern classification in memory centers such as olfactory cortex. Whitening cannot be explained by global scaling or thresholding operations but requires structured interactions between specific subsets of neurons. To analyze mechanisms of whitening we measured odor-evoked activity throughout the OB of a zebrafish larva by two-photon calcium imaging and subsequently reconstructed the full wiring diagram by volume electron microscopy. This “dynamical connectomics” approach revealed an overrepresentation of triplet connectivity motifs that privileges multisynaptic reciprocal inhibition among mitral cells with similar tuning. Tuning-dependent multisynaptic connectivity specifically suppressed activity of output neurons that respond to odors particular olfactory features. Connectivity in the OB therefore suppresses the representation of specific features, which reduces the correlation between representations of related odors. This specific neuronal connectivity was necessary and sufficient to reproduce whitening of natural input patterns in generic network models. We therefore concluded that whitening in the OB is achieved by higher-order structure in the wiring diagram that is adapted to natural input patterns. These results provide direct insights into the network mechanism underlying a fundamental neural computation and illustrate the potential of “dynamical connectomics” approaches to analyze complex structure-function relationships in neuronal circuits.

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Invited by Hermann Kohlstedt
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