Odor identity coding reveals parallel processing within the bee’s dual olfactory pathway

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In their natural environment animals are faced with complex and highly dynamic olfactory input. This demands fast and reliable information processing in olfactory systems of both vertebrates and invertebrates. Parallel processing was shown to improve processing speed and power in the auditory, visual, and somatosensory system and is characterized as extraction of different parameters along parallel sensory information streams. For instance, in the visual system the magno- and parvocellular pathways from the lateral geniculate nucleus mediate different elemental properties of the same visual scene such as color and spatio-temporal patterns (Livingstone & Hubel, 1988 Science 240:740-749). Honeybees possess an elaborate olfactory system with unique neuronal architecture, a dual olfactory pathway comprising a medial and lateral projection-neuron (PN) output tract (m-, l-APT) connecting the olfactory lobes with higher order brain centers. This peculiarity is exclusively found in Hymenoptera (e.g. bees, ants, wasps; Rössler & Zube, 2011 Arthropod Struct Dev 40:349-357). Here, we used this specific adaptation as a model system to address the importance of parallel processing in olfaction.

We employed a novel experimental technique for simultaneous multi-unit recordings from both antennal-lobe output tracts. This revealed detailed response profile characteristics of high numbers of PNs to a variety of floral, pheromonal and biologically relevant odors. PNs of both tracts responded to all tested odors, but with different characteristics indicating parallel processing. L-APT PNs were activated by multiple odors (broad response profiles) suggesting generalized odor coding, whereas m-APT PNs responded with sparse activity pattern and high odor-specificity. Comparison of response latencies of PNs within and across both output streams revealed odor-dependent latency patterns that likely support a dual tract temporal code, possibly promoting coincidence coding at the level of the mushroom body input, which could have important implications for olfactory learning and memory (e.g. Heisenberg, 2003 Nat Rev Neurosci 4:266–275).

We conclude that parallel processing via the honeybee’s dual olfactory pathway enhances performance for sophisticated odor perception as required under complex natural stimulus conditions of a social insect. Comparison with recent work on olfactory systems in rodents (e.g. Igarashi, Ieki et al., 2012 J Neurosci 32:7970–7985) indicates that parallel processing of olfactory output might be a common principle across distant taxa.

Supported by DFG SPP 1392 (RO 1177/5-1) and BMBF (01GQ0941).