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Navigating in turbulent worlds: High speed smelling in honeybees

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Bees memorize odors of visited flowers. These odors are mixtures of different chemicals. However, odor-driven behaviors require perceiving such odor mixtures as unitary odor-objects. This task is difficult in a turbulent world: airborne odors are transported by wind and form erratic and overlapping plumes, similar to cigarette smoke. Consequently, odors from different sources intermingle in temporally unpredictable mixtures. The question arises how bees disentangle such overlapping stimuli. We hypothesize that minute time differences between plumes are exploited by bees to recognize the relevant odors. Here we probe the limits of insects' olfactory temporal resolution by delivering high frequency odor pulses and measuring sensory responses in the antennae. We show that transduction times and pulse tracking capabilities of olfactory receptor neurons (ORNs) are 10 to 30 times faster than previously thought. Once an odorant arrives at the boundary layer of the antenna, signal transduction can start as fast as in 1.1 milliseconds. The temporal resolution increased with increasing stimulus duration. Thus, insect ORNs can track very short stimulus durations as their antennae encounter narrow filaments in an odor plume. These results provide a new upper bound to the kinetics of odor tracking in animals and to the latency of initial transduction events in olfaction. Rapid tracking is likely necessary for odor-background segregation and odor source location in insects. Using in-vivo calcium imaging in the honeybee brain, we show that bees can exploit short temporal asynchronies between odor stimulus onsets to segregate odors from different sources. Consistent with bee's behavioral performance, projection neuron responses in the antennal lobe are sensitive to millisecond stimulus asynchrony: Compared to synchronous mixtures, the responses to asynchronous mixtures contain more information about the components. A detailed analysis shows that the antennal lobe creates a 'slow motion' effect, aiding memory retrieval and possibly encoding.