Supplementary Information (SI) Guide

Supplementary information guide for Odor motion sensing enhances navigation of complex plumes by N. Kadakia, M. Demir, B. T. Michaelis, B. D. DeAngelis, M. A. Reidenbach, D. A. Clark, T. Emonet.

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1. Supplementary Discussion (pages 1-4). Additional discussion of i) the HRC model in odor motion sensing and its comparison to visual motion sensing and ii) the role of antennal size, active sensing, and flight in odor motion sensing.
SUPPLEMENTAL DISCUSSION

Further discussion of HRC model in odor motion sensing

While the HRC model replicates several features of odor direction sensing, it is an incomplete description of the odor motion sensing algorithm. First, HRC responses to ON and OFF edges are necessarily symmetric (Methods), while we find asymmetries between ON and OFF edge responses (Extended Data Fig. 3e), which are also found in visual motion detection\textsuperscript{59-62}. Secondly, the HRC computes only second-order correlations – correlations between pairs of points in space and time – while in vision, higher-order correlations can also elicit direction-selective behaviors\textsuperscript{59,63}, and may improve motion detection by exploiting the statistics of natural scenes\textsuperscript{64-66}. Natural odor landscapes also exhibit universal highly-structured statistics\textsuperscript{67} to which odor direction selective computations may likewise be tuned.

In mouse retina and fly vision, motion detection circuits have been characterized in detail and have many parallels\textsuperscript{68,69}, though much remains unknown. In both, visual motion is computed separately for ON and OFF edges\textsuperscript{70-72}, and it is likely that a similar split may exist in odor motion computations, given the difference in responses to ON and OFF edges in the presence of wind (Extended Data Figs. 4a-d). Still, our results do not implicate any specific circuit architecture or mechanism. In fly vision, direction selective behaviors and signals are frequently well-described by pairwise correlator models\textsuperscript{61,73}, while the underlying neural architectures and functional interactions perform a rich suite of computations that extend beyond sensitivity to pairwise correlations\textsuperscript{74-82}. Ultimately, comparisons between odor and visual motion detection systems will reveal how circuits in these distinct modalities accomplish similar tasks.

Role of antennal size, active sensing, and locomotive regime in odor motion sensing

Beyond \textit{Drosophila}, odor lateralization has been observed in many other animals\textsuperscript{83-85} including humans\textsuperscript{86}. This suggests that odor motion sensing may not be unique to insects, but it also raises an interesting question of timescales. For example, for rats to resolve odor motion at the speeds we find here, the HRC timescale would have to increase by the ratio of rat nostril separation to fly antennal separation – more than ten times. This suggests the interesting possibility that the timescales of motion detectors increase with the size of the peripheral olfactory anatomy – a testable prediction. Another aspect we have not considered here is active sampling of the environment, such as by moving the antennae. Active sampling critical to odor navigation in animals with larger olfactory appendages, such as lobsters\textsuperscript{87}, and could play a role odor motion percepts by modulating the inter-antennal spacing, and therefore the odor velocity tuning. Finally, our work has demonstrated odor motion sensing via comparisons between antennae, but odor motion could in principle also be computed by ORNs along a single antenna, since ORN types are restricted to distinct regions on the antenna\textsuperscript{88}. The importance of spatial information along
one antenna has been implicated in navigation, albeit in insects whose antennae are orders of magnitude longer\(^89\).

Insects can sense the wind direction\(^90,91\) and are known to bias their heading upwind when odors become longer, more intense, or more frequent\(^92-100\). This strategy fails at the plume edges, where insects resort to local search or downwind or crosswind motion to re-enter the plume\(^95,99,101,102\). In this sense, the value of the lateral odor motion is evident, providing cues about which crosswind direction to take to move closer to the center of the plume. Our work does not explore odor direction sensing in the z-dimension – say, for flying insects. The role of odor direction sensing would likely be different, since odors traveling upward would not be sensed bilaterally unless the insect were flying with nonzero roll.

REFERENCES


