Poster: 15

A neurocomputational theory of olfactory recognition

(NIDCD R01-DC06104 FY 02)

Zachary Mainen
Cold Spring Harbor Laboratory

Carlos Brody
Cold Spring Harbor Laboratory

Psychophysical studies in rodents show that even difficult olfactory discriminations can be performed accurately within ~300 ms on the basis of a single sniff cycle with theta frequency (7-8 Hz) (Uchida and Mainen, 2003). These results suggested that a sniff cycle might constitute a unit of odor coding and a basis for the rapid odor coding.

To examine the neural mechanisms of rapid olfactory discrimination, we monitored the activity of neurons in the anterior piriform cortex using tetrodes in rats performing an olfactory discrimination task with two choice directions (Uchida and Mainen, 2003). Respiration was simultaneously recorded. During the recording sessions, two to four pure odor pairs were used, as well as binary mixtures of these pairs.

Piriform cortex responses were robust and widely distributed. For neurons tested with >= 6 odors, over half showed a significant response to at least one odor. Responses were approximately evenly distributed between excitatory and inhibitory activity.

For responsive neurons, spikes were locked to the sniff cycle. Typical responses constituted of a fast transient (~50 ms duration) with a fixed latency (<100 ms) from the inhalation onset. When the rat took two or more sniffs before the choice, spike frequency adaptation was variable.

To quantify the time course of the development of piriform odor representations, the ability of single neurons to discriminate between odor pairs was quantified by ROC analysis using either sliding window or cumulative spike counts. These analyses showed discriminability developed rapidly, usually peaking or saturating within 100 ms of the onset of the first odor inhalation. Some single neurons could discriminate odor pairs with accuracy comparable to that of the animal.

These results indicate that piriform cortex neurons represent odor information in a dense distributed code and that the respiratory cycle strongly patterns the flow of this information, delivering a substantial fraction of it within the first sniff (< 200 msec). We suggest that spike rates across ensembles of neurons are likely to be sufficient to account for the speed and accuracy of elementary odor discriminations.

Project (or PI) Website

http://www.cshl.edu/public/SCIENCE/mainen.html

Publications

1. Uchida N, Mainen ZF (2003) Speed and accuracy of olfactory discrimination in the rat. Nature Neurosci 6, 1224-1229.

2. Hopfield JJ, Brody CD (2003). Separating objects and 'neural' computation. C R Biol. 326:219-22.

3. Brody CD, Hopfield JJ (2003) Simple networks for spike-timing-based computation, with application to olfactory processing. Neuron 37:843-52.

4. Hopfield JJ, Brody CD. (2004) Learning rules and network repair in spike-timing-based computation networks. Proc Natl Acad Sci U S A 101:337-42.

5. Egger V, Svoboda K, Mainen ZF (2005) Dendrodendritic synaptic signals in olfactory bulb granule cells: local spine boost and global low-threshold spike. J Neurosci 25, 3521-30.

6. Machens CK, Romo R, Brody CD (2005) Flexible control of mutual inhibition: a neural model of two-interval discrimination. Science 307:1121-4.

7. Kepecs A, Uchida N, Mainen ZF (2006) The sniff as a unit of olfactory processing. Chem Senses 31, 167-79.

8. Wilson R, Mainen ZF (2006) Early events in olfactory processing. Annu Rev Neurosci, in press.

9. Uchida N, Kepecs A, Mainen ZF (2006) Seeing at a glance: Limits on temporal integration in perception. Nature Rev Neurosci, in press.