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The Spatial Representation of Odors by Olfactory Receptor Neuron Input to the Olfactory Bulb is Concentration Invariant

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We wish to understand how odorants are distinguished and how one odorant is recognized as the same across a concentration range of several orders of magnitude. To this end we have measured the spatial pattern of the olfactory receptor neuron input to the olfactory bulb in the three-toed box turtle (*Terepene triunguis*).

To monitor the input to the bulb we labeled the nerve terminals of the olfactory receptor neurons with Calcium Green-1 dextran 10 kD (Molecular Probes) following the method developed by Friedrich and Korsching (1). We then formed a magnified (4×) image of the bulb on an 80 × 80 CCD camera (NeuroCCD; RedShirtImaging, LLC, Fairfield, CT) and recorded the changes in

fluorescence that resulted from a 2-s odorant pulse delivered to the nose. The signals we measured had approximately the same time-course everywhere in the bulb, and we therefore characterized the response by the amplitude of the signal as a function of its position on the bulb.

Figure 1 shows three pseudocolor representations of activity in response to the odorant, hexanone. Red represents a large signal in each measurement and blue represents a signal 30% as large. The left-hand image shows the response to hexanone at a concentration that was 0.3% of saturation. The largest signal in the response was colored red (normalized scaling). Both right-hand images show the

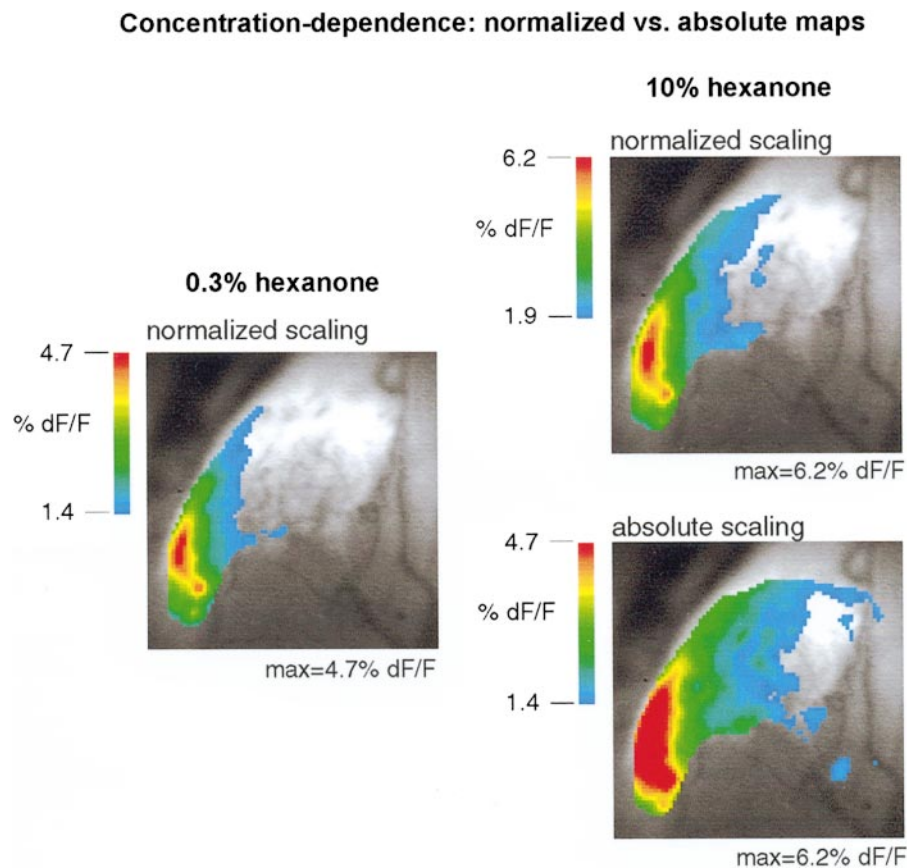


Figure 1. Normalized maps of receptor neuron input to the turtle olfactory bulb are concentration-invariant. The left panel shows a pseudocolor map of the response to a 0.3% dilution of saturated vapor of 2-hexanone. The map is normalized to the maximum signal amplitude for this trial. The right panels show pseudocolor maps of the response to a 10% dilution of 2-hexanone. The map on the top is normalized to its maximum signal amplitude. The map on the bottom (absolute scaling) shows the same data using the same scaling as for the 0.3% hexanone trial. The figure shows a concentration-dependent increase in the number of glomeruli activated above a given absolute level, but shows concentration-invariance in the relative levels of input to all glomeruli activated by an odorant. 4× image magnification. The field of view is approximately 4 mm × 4 mm.

response to 10% hexanone using two different scaling procedures. The bottom image shows the response using the same scale as that used for the response to 0.3% hexanone (absolute scaling). This image is qualitatively different from the 0.3% image. In contrast, the top image shows the response using normalized scaling. Again, the largest signal was colored red. This image is essentially identical to the image on the left, even though the concentration of odorant differed by a factor of 30. Thus, normalized maps of input to the olfactory bulb appear to be concentration invariant.

We hypothesize that concentration invariant odorant identifica-

tion could be achieved if higher olfactory centers “read” the normalized maps of the input to the olfactory bulb.

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Literature Cited

1. Friedrich, R., and S. Korsching. 1997. *Neuron* 18: 737–752.