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Extracting concentration-invariant odour subspaces through competitive receptor-ligand interactions

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Robust identification of natural odours poses several difficult problems. First, odours exist in nature as a diversity of mixtures of tens or even hundreds of chemical compounds, with concentrations spanning at least ten orders of magnitude. Thus the olfactory sensory neuron population must be sensitive to a wide variety of stimuli and concentrations while avoiding saturating its response. Second, the animal must identify the odour independently of its concentration over a large range. How these two problems are solved together is not clear. Here we describe how fundamental biophysical mechanisms of receptor-ligand competition account for experimental data reporting nonlinear interactions between mixture compounds at olfactory receptors. We demonstrate how this competition leads naturally to neuronal responses which depend upon the ratios of these mixtures. Our competitive interaction model demonstrates that for high dimensional odour stimuli this ratio coding principle provides an efficient solution to these problems by extracting invariant features that depend on the relative concentrations of the mixture components. Surprisingly, such nonlinear interactions at olfactory receptors are found to simplify the coding of highly dimensional stimuli and may have important consequences for understanding how the olfactory pathway processes complex chemical information.

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