Olfaction workshop, 26 July 2012 at CNS*2012

Coding of temporally incoherent odour mixtures in the antennal lobe of honeybees

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In recent behavioural experiments with honeybees, Apis mellifera, we have found that the animals are able to distinguish coherent odour mixtures, where both odours arrive at the same time, from incoherent odour mixtures where the onset of one odour is delayed. Surprisingly this ability persisted down to an onset delay of only 6 ms. Moreover, the ability of bees to segregate the mixture components is facilitated in incoherent mixtures. In this work we explore this surprising ability in a model of the honeybee antennal lobe (AL). We hypothesise that a winner-take-all inhibitory network of local neurons (LNs) in the AL could have a symmetry-breaking effect, such that the response pattern to an incoherent mixture is measurably different from the response pattern to the corresponding coherent mixture for an extended amount of time beyond odour onset.

Although we are still just at the beginning of this work we have already found that we (i) can approximate the experimentally observed response patterns in the AL model, (ii) the winner-take-all LN network does lead to different winners for different odours and, importantly, for different incoherent mixtures and (iii) the influence of the LN network leads to measurably different PN responses for different incoherent and the corresponding coherent mixtures. We tested the model on hexanol, octanol, their coherent mixture and temporally incoherent mixtures. To analyse the results we calculated “template responses” to the individual odours and the coherent mixture as the average of PN spike density functions (SDFs) in all glomeruli in the interval from 100 to 200ms after odour onset. We then calculated the correlation of the instantaneous PN SDF values of responses to incoherent mixtures with these response templates. We observe that the incoherent mixture with hexanol first is initially most similar to the response template of the coherent mixture, but eventually becomes more similar to the pure octanol response. The response to the octanol-first incoherent mixture is also initially more similar to the coherent mixture but then becomes more similar to the hexanol response pattern. This demonstrates that, although the incoherent mixtures only had a microscopic delay of 10ms on this occasion, the responses are markedly different for the two incoherent mixtures and the coherent mixture for a macroscopic amount of time during the response. This difference could easily be exploited by the animals to recognise the incoherent mixtures against each other and against the coherent mixture.

Odours are encountered by the bees in thin filaments in turbulent odour plumes. Odour mixtures emanating from the same odour source will arrive within the same filaments, i.e. as coherent mixtures, while odorants from separate odour sources that are mixed in the air would arrive in different filaments leading to incoherent mixtures. The ability of bees to distinguish incoherent and coherent mixtures could hence underlie a form of “odour object recognition” to help making sense of the complex odorant scene encountered by the animals.

In future work we will test our predictions in physiological experiments in the bee antennal lobe to confirm, falsify or further refine the model. We will perform more systematic explorations of the model to establish the extent of possible response characteristics depending on the model parameters and we will analyse the limitations of incoherent mixture perception given realistic constraints from the anatomy and physiology of the bee brain.