Supplementary Note

Readout of category information by coincidence detection

The results suggest that information about odor identity and category may be extracted selectively from the same MC activity patterns by varying the sensitivity of the readout to phase-locked spiking. Low sensitivity to phase-locked spiking could be achieved simply by integrating MC activity over one or more oscillation cycles. Indeed, previous results have shown that activity patterns integrated over tens or a few hundred milliseconds are well suited for determining odor identity[1, 2].

Higher sensitivity to phase-locked spikes could be achieved by integrating MC activity over shorter times. However, since phase-locked spikes are the minority, detection of phase-locked spike patterns may be complicated by the background activity of other, non-phase-locking MCs. We therefore tested whether category information can be retrieved from MC firing patterns by a hypothetical target neuron with a short integration time constant. The target neuron is not meant to represent an existing neuron type downstream of the OB, the integrative properties of which are not known in fish. It only implements a simple detection scheme with biologically realistic properties. Kenyon cells of the insect mushroom body are in a comparable position of the olfactory pathway and have nonlinear properties similar to those assumed for target neurons in the model[3, 4].

The experimentally measured MC response patterns were used to model odor-evoked inputs to the target neuron. The average number of phase-locked and residual spikes per cycle was determined for each recorded MC and odor at a given time after response onset (usually 1,000˚ms). Spiking patterns across MCs, with phase-locked and residual spike rates matching the experimentally determined rates for each MC and odor, were then reconstructed for one oscillation cycle. The temporal occurrence of spikes during the cycle followed different probability distributions: the probability of phase-locked spikes followed a gaussian

spikes was uniform throughout the cycle (**Supplementary Fig.˚5a**). The target neuron was then connected to subsets of MCs that responded with synchronized spikes to odors of a selected cluster (**Supplementary Fig.˚5b**). Thus, the total input to the target neuron consisted of the phase-locked and residual spikes of a subset of MCs. Each input spike elicited a short (5 ms), single-exponential decay voltage response in the target neuron. The summed voltage responses in the target neuron were determined for 40 trials of each odor, with new random spike times drawn from the given probability distributions in each trial.

The summed voltage responses to odors of the selected cluster reached higher values than responses to other odors and could be isolated by thresholding. This is shown in **Supplementary Fig.˚5c** for a target neuron receiving input from 11 MCs responding with partially synchronized spikes to one or multiple odors from the first cluster (gray shading; cluster 1 in **Fig. 7b**). Each MC could also respond to other odors. Nevertheless, the target neuron was highly selective for the selected odor group. Moreover, even though the model parameters (connectivity and threshold) were derived from MC spiking patterns 1,000 ms after response onset, the target neuron s selectivity persisted throughout stimulus presentation (**Supplementary Fig.˚5d**). Hence, the artificial target neuron acts as a robust category detector. Conceivably, larger sets of MCs, inhibitory interactions between target neurons, and the adjustment of synaptic weights could further enhance the specificity of target neurons.

If information about category and identity conveyed by MC activity patterns is to be useful to the brain, it has to be accessible selectively by biologically plausible mechanisms. Amino acid identity can simply be extracted from MC firing patterns by temporal integration of firing rates[1, 2]. Patterns of phase-locked spiking, on the other hand, can detected against the high background of residual spikes by coincidence detection, as demonstrated by the simple model. The connectivity between MCs and the model s target neurons, as well as the target neuron properties, were not optimized systematically. Furthermore, targets of MCs in the

model. These connections may enhance the sensitivity to coincident input and the selectivity for input patterns[3, 5]. Thus, our model was intentionally much simpler than the real biological system. The fact that it nevertheless retrieved category information indicates that patterns of phase-locked OB output are salient enough for reliable detection even without complex processing in the target area.

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