Data analysis. All analyses were performed using Matlab (TheMathWorks) or IgorPro (Wavemetrics). Spatial and temporal filtering were performed offline using non-phase shifting procedures.

To construct phase maps of the optically recorded oscillation, the peak time of the optical signal was determined for each pixel. The phase of this peak time relative to the optical oscillation averaged over a large region was then determined by a procedure equivalent to the quantification of spike phases (see below). A constant value was then added to the resulting phase map to make all phase values positive for easier evaluation.

To represent the optically recorded wave propagation by a vector, a map of oscillation peak times was constructed, equivalent to the corresponding phase map. The time resolution is given by the data acquisition rate (1°ms/frame). Oscillation peak times were then expressed relative to the oscillation peak time of the signal averaged over a large region. For each relative peak time between —5 and 5 ms, a map was constructed in which pixels of the respective peak time were assigned a value $I(x_i, y_i)$ of one, while other pixels were set to zero. For each map, the center of gravity was determined as

$$(x_{c.g.}(t_{peak}), y_{c.g.}(t_{peak})) = \Sigma\, (x_i, y_i) * I(x_i, y_i) / n,$$

where $x_{c.g}(t_{peak})$., $y_{c.g.}(t_{peak})$ are the coordinates of the center of gravity for peak time t_{peak}, x_i and y_i are the coordinates of the i^{th} pixel, $I(x_i, y_i)$ is the value of the i^{th} pixel (0 or 1), and n is the total number of pixels. Vectors representing the translation of the center of gravity between maps of peak times differing by 1°ms were then calculated as $v = (x_{c.g.}(t_{peak} + 1), y_{c.g.}(t_{peak} + 1)) - (x_{c.g.}(t_{peak}), y_{c.g.}(t_{peak}))$. These vectors were then averaged to obtain a vector describing the average direction and velocity of wave propagation. Quantitative analysis of wave propagation was restricted to the five experiments with the highest signal-to-noise ratio because the center of gravity analysis is sensitive to outliers that can arise from noise. However, wave propagation was also clearly apparent in the remaining 10 experiments.

The phase, ϕ, of single spikes relative to the LFP oscillation recorded on the same electrode was determined from the relative temporal position of a spike between the neighbouring maxima and minima of the oscillation: $\phi = (t_{spike} - t_{peak, before}) / (t_{peak, after} - t_{peak, before}) * 360$, where t_{spike} is the time of occurrence of the spike, and $t_{peak, before}$ and $t_{peak, after}$ are the times of occurrence of the LFP maxima immediately before and after t_{spike}, respectively. Determining spike phases relative to the minima of the LFP oscillation and subtracting 180° gave equivalent results. Mean spike phases during the oscillatory part of the odor response were calculated as the average spike phase in a two second time window, starting 400 ms after response onset. Spike phases were averaged using a vector-based procedure that takes into account the circular nature of the data.

Cross-correlograms were determined from 1.9 second segments of data, starting 500˚ms after response onset, when oscillatory activity was prominent. Spike trains were convolved with a gaussian kernel (σ˚=˚10˚ms) before cross-correlation. Phase shifts, $\Delta\phi$, between LFP traces or spike trains were determined by the temporal offset of the central peak in the cross-correlogram, relative to the oscillation period given by the time difference between neighbouring peaks: $\Delta\phi = t_{peak, center} / (t_{peak, center} - t_{peak, left}) * 360$, where $t_{peak, center}$ is the correlation time of the central maximum of the cross-correlogram and $t_{peak, left}$ is the correlation time of the maximum on the left of the central maximum. Using the maximum on the right of the central maximun gave equivalent results. Values of phase shifts can be negative or positive, depending on the arbitrary sequence of data input into the calculation of the cross-correlation. In order to facilitate data viewing, phase shift values between LFPs and the corresponding MC spike trains from paired recordings were both multiplied by -1 when the phase shift between LFPs was negative. This does not affect the results. Thus, all shown phase shifts between LFPs in paired recordings are positive, while phase shifts between spike trains can be positive or negative. In **Supplementary Fig.˚1**, absolute phase shifts are plotted, independent of their direction. For the construction of phase maps from multisite LFP recordings (**Fig. 2a**) one electrode was always used as a reference, and signs of phase shifts were never changed.

Factor analysis was done as described[1, 2]. The clustering index (**Figs. 6f, 7a**) is the maximum factor loading on each odor, averaged over all odors. The maximum loading incidates the cluster (factor) with which each odor is primarily associated, and its value indicates the tightness of this association. Hence, the derived index reflects the average tightness of clustering.

The CV of firing rates was used as a measure of response variability independent of the absolute firing rate (**Fig. 6g**). It is calculated as the SD divided by the mean of firing rates evoked by repeated applications of the same odor in a given time window. CVs for each MC and odor were averaged. In some cases, the average firing rate within a given analysis window for a given odor was zero; the CV is then not defined. In this case the CV was set to zero[3].

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