Localizing the human olfactory cortex: a meta-analytic approach

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MOTIVATION:

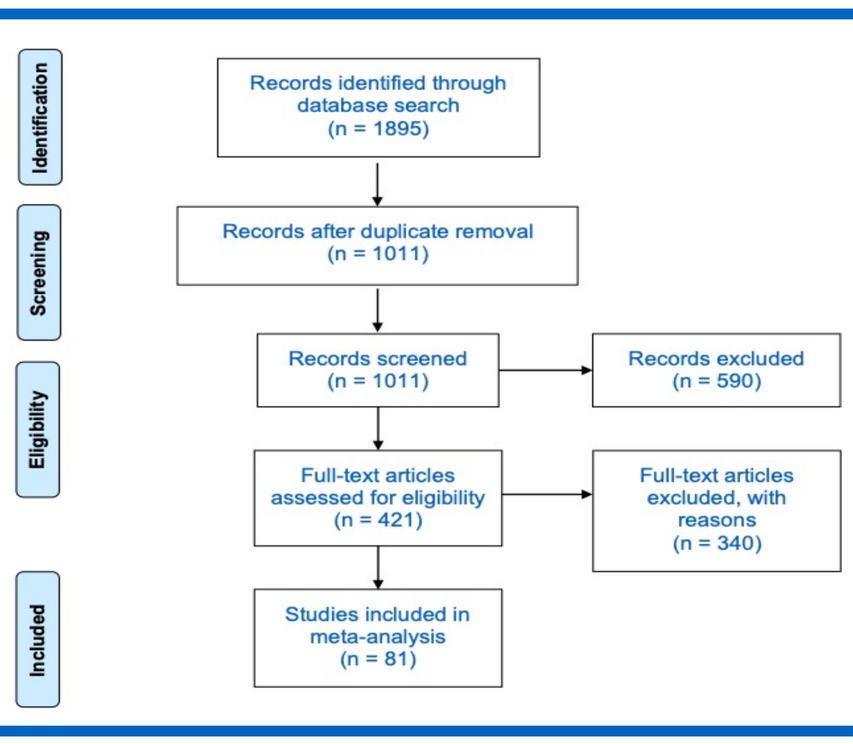
The human sense of smell, through its ability to detect and distinguish odors, allows for the extraction of valuable information from the environment. In order to gain a better understanding of the human olfactory system and its individual processing nodes, this meta-analysis aims to quantify all relevant and available neuroimaging data using the activation likelihood estimation (ALE) method.

METHODS:

The protocol of this meta-analysis was pre-registered to the PROSPERO database:**CRD42020157138**

Literature search: Search terms were selected to identify all relevant literature published prior to May 2020 for all odors, pleasant-, food-, and aversive odors using PubMed, Google Scholar, and SCOPUS.

Literature search results:



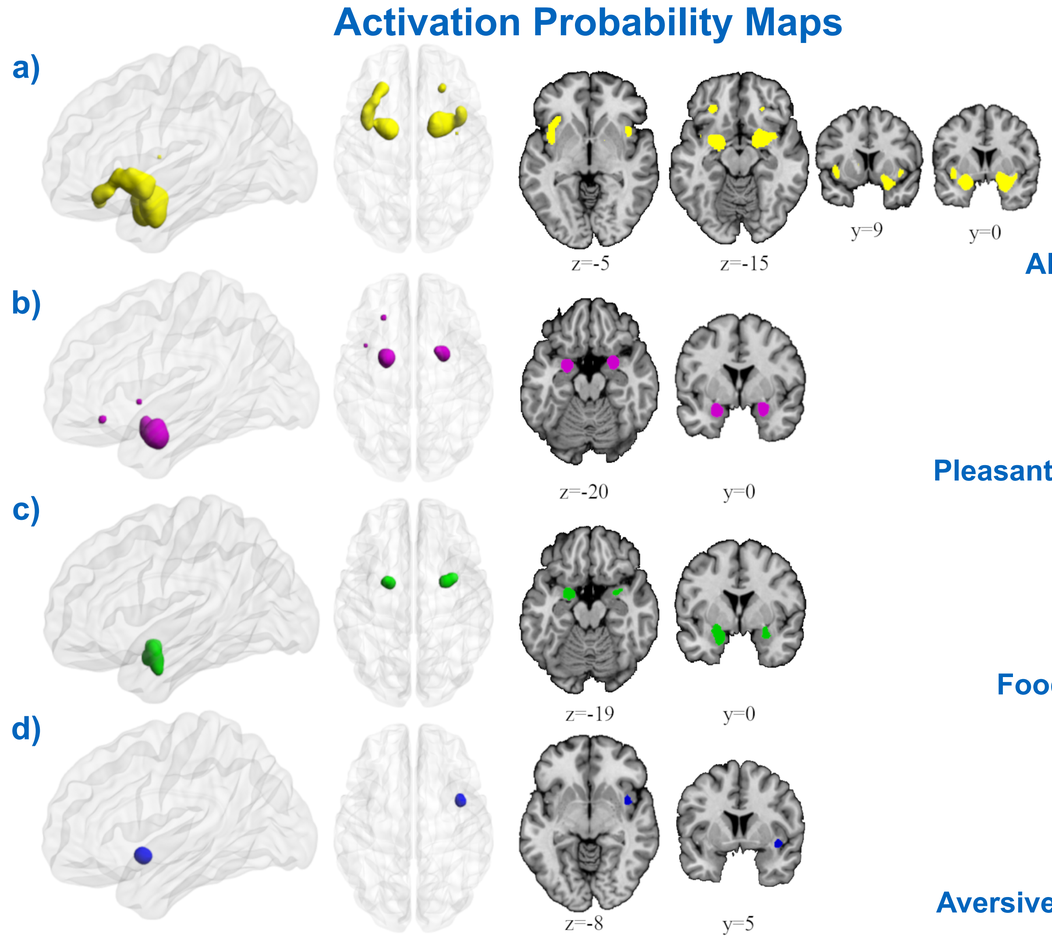
Activation Likelihood Estimation (ALE):

The ALE algorithm, developed by Eickhoff et al., 2009, quantifies the inter-study concordance of empirical neuroimaging studies. The x-, y-, and z-coordinates of peak activations (or foci) are entered into the algorithm and are converted to standardized coordinate space. The foci are modeled as 3D Gaussian probability distributions centered at the given foci. The Gaussian widths are calculated based on the number of subjects represented in each foci. Individual maps of activation likelihood (MA maps) are calculated for each study by taking the voxel wise union of the Gaussians for all foci derived from that contrast. Subsequent permutation analyses of randomly generates sets of coordinates and calculates the voxel-wise union of MA maps *across* experiments. This allows for the ability to distinguish between truly converging foci across studies and noise i.e., to identify brain regions that show a consistent response across studies (Eickhoff et al., 2012). Resulting MA maps are corrected at $p < 0.05$ family-wise error (FWE) at the voxel level.

ALE contrast analysis: two sets of foci are examined for significant differences in convergence. To account for potential differences between the studies, the algorithm generates a null-distribution under the null-hypothesis of label exchangeability by randomly reassigning labels to the datasets (which is equivalent to randomly redistributing the studies into two groups) and computes the difference for the two datasets. Many permutations of this step are executed thereby ultimately yielding the null-distribution of the ALE difference which are then thresholded (Eickhoff et al., 2011).

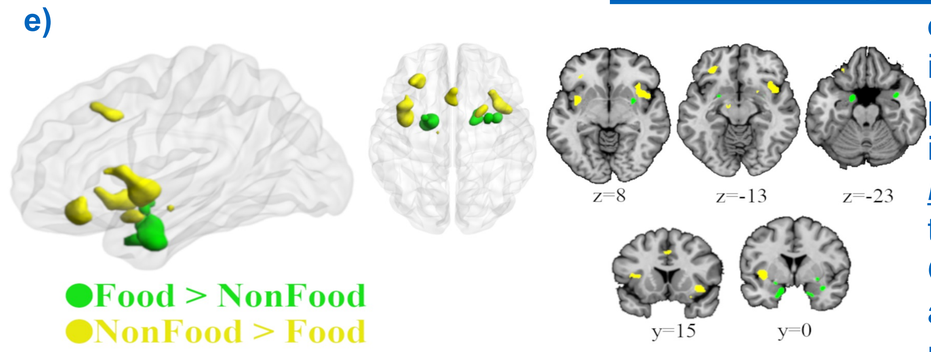
RESULTS :

Activation Probability Maps

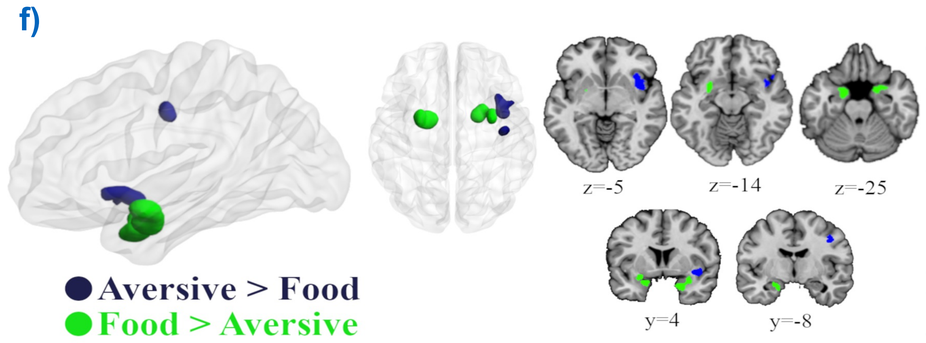


a) All odor ALE: activations observed in the amygdala, piriform cortex, OFC, and insula.
b) Pleasant odor ALE: activations observed in the amygdala, piriform cortex, OFC, insula, pallidum, putamen, and central opercular cortex.
c) Food odor ALE: activations observed in the amygdala, piriform cortex, parahippocampal gyrus, and entorhinal cortex.
d) Aversive odor ALE: activations observed in the right insula, postcentral gyrus, and amygdala.

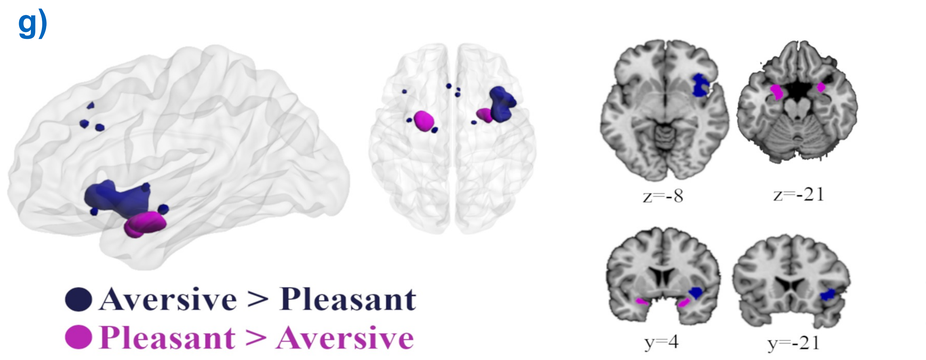
Contrast Analyses Results



e) *food > nonfood* activations observed in the entorhinal cortex, amygdala, piriform cortex, parahippocampal gyrus, insula and putamen.
nonfood > food activations observed in the insula, frontal operculum cortex, OFC, cingulate and paracingulate gyrus, amygdala, piriform cortex, putamen, and pallidum.



f) *food > aversive* activations observed in the left amygdala, piriform cortex, hippocampus, parahippocampal gyrus, temporal pole, entorhinal cortex, left pallidum, and left putamen.
aversive > food activations observed in the insula, OFC, precentral gyrus, middle frontal gyrus, and postcentral gyrus



g) *pleasant > aversive* activations observed in the left hippocampus, amygdala, parahippocampal gyrus, OFC, and temporal pole.
aversive > pleasant activations observed in the insula, amygdala, hippocampus, frontal occipital cortex, temporal pole, frontal operculum, and cingulate gyrus

CONCLUSION:

With this meta-analysis we are successfully able to contribute to the neuroimaging and chemosensory scientific communities by providing activation probability maps of the human olfactory cortex and its individual processing nodes for specific odor categories. We hope to provide many disciplines with further insight into the neural processing of odors.
*** **All foci coordinates, activation probability maps, and supplemental information are available on ANIMA (https://anima.fz- juelich.de/)**

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REFERENCES: Eickhoff, S.B., Laird, A.R., Grefkes, C., Wang, L.E., Zilles, K., Fox, P.T., 2009. Coordinate- based activation likelihood estimation meta-analysis of neuroimaging data: a random-effects approach based on empirical estimates of spatial uncertainty. Hum. Brain Mapp. 30 (9), 2907 2926. Eickhoff, S.B., Bzdok, D., Laird, A.R., Roski, C., Caspers, S., Zilles, K., Fox, P.T., 2011. Co- activation patterns distinguish cortical modules, their connectivity and functional differentiation. Neuroimage 57 (3), 938 949.