

Multimodal food perception: meta-analysis of neuroimaging studies of food cues

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INTRODUCTION Obesity is at an epidemic proportion, affecting one-third of American adults and 17% of American children. Many studies have sought to utilize human functional neuroimaging techniques to understand how the brain is affected by food and food cues. Results are highly variable due to intersubject variability and differences in experimental design. Hence, neural systems affected by food cues remain incompletely understood. Insight into the neurobiological mechanisms at play in the obesity spectrum would benefit from a robust, generalizable model of neural network underlying perception of food and the craving. We utilized a coordinate-based meta-analytic approach (ALE), which allows findings from multiple studies to be examined for consensus of brain regions typically involved in a given task. The goal of this work was to develop a meta-analytic model of neural systems related to multimodal perception of food and craving by examining prior publications in visual, taste and olfactory food stimulation.

METHODS fMRI and PET studies investigating the neural correlates of visual, olfactory, and taste food stimuli were selected using the PubMed database. Studies included investigations of healthy, lean subjects (BMI= 18.5 -25 kg/m²) that were published in peer-reviewed journals and reported the peak locations of whole-brain activations in the form of stereotactic coordinates (Montreal Neurological Institute (MNI) or Talairach space). Three sets of studies were identified as follows: 1) Visual food cues studies: Studies examining visual presentation of pictures of high caloric content food contrasted with nonfood pictures were identified using the keywords of "food" AND "pictures" (12 experiments from 11 publications reporting 109 brain activation locations across a total of 201 participants were selected). 2) Taste food studies: Studies in which subjects ingested food products to study the neural substrates associated with taste responses by contrasting food taste with tasteless solution were identified using the keywords of "milkshake" OR "meal" OR "chocolate" OR "eating" OR "drinking" OR "sucrose" OR "glucose." (11 experiments from 8 publications reporting 89 peak coordinates from a total of 146 participants were included). 3) Olfactory food cues studies: Studies presenting subjects with food and other appetizing odors contrasted with odorless solutions or unpleasant odors were identified using the keywords of "odor" OR "smell" OR "olfactory". (8 experiments from 8 publications across a total of 131 participants, and these experiments reported 79 coordinates).

RESULTS Figure 1 shows significant ALE cluster for visual, taste and olfactory food cues in lean subjects. Overlays of multiple comparisons between different food cues presentations are shown in Figure 2. Insula and parahippocampus (light blue) are common areas to olfactory (green) and taste food cues (blue). Insula and inferior frontal gyrus (yellow) are common to visual (red) and odor food cues (green). Only insula (purple) is common to visual (red) and taste food cues (blue). Only insula is the common to the three analyses.

DISCUSSION Comparison of ALE meta-analysis results across different modalities showed that some neural systems are task specific and some are common across different modalities. During the visual food cues, superior temporal and postcentral gyrus activation may be related to somatosensory stimulation originated by evoking taste or smell. Engagement of hippocampus and parahippocampus may be due to retrieval of taste or smell information related to the stimuli. Orbitofrontal cortex receives inputs from the gustatory, olfactory, somatosensory, auditory and visual brain areas¹. Regarding brain regions activated during olfaction, anterior cingulate and postcentral gyrus activation may be related to somatosensory stimulation of the oral cavity. Precentral and middle frontal gyrus activation may be due to mouth opening and tongue movement. Activation of parahippocampus has been related to interoceptive signaling of satiety². From the results of olfactory food cues, activation of cingulate cortex, piriform cortex, OFC, superior temporal gyrus and hippocampus are common during olfactory tasks. Comparison of olfactory and visual food cues may give us insights into the brain areas engaged during food craving. Inferior frontal gyrus (OFC) and insula have been implicated in craving studies, such as nicotine and drugs. The results of our study show similar recruitment of neural systems between drug and food craving, corroborating previous research³. The findings that the insula is involved during multimodal presentation of food cues may be explained by the role of insula in sensory integration and taste memory.

CONCLUSION This study used meta-analysis technique to identify and compare concordant brain areas involved in multimodal food perception, such as taste, olfactory, and visual food cues. This work has the potential to improve understanding of hunger and craving, and has the potential to help develop novel therapeutic strategies targeting obesity by identifying abnormalities in function during multimodal perception of food cues.

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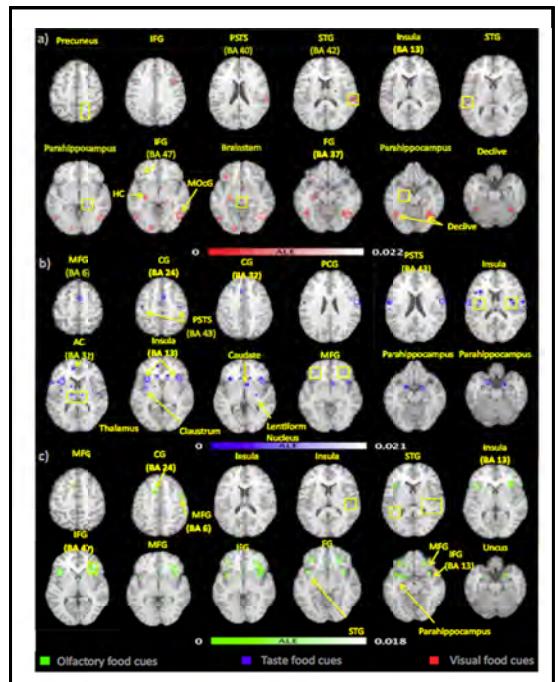


Figure 1.(a) Significant ALE clusters for the visual food cues. (b) Significant ALE clusters for taste food cues. (c) Significant ALE clusters for the odor food cues.

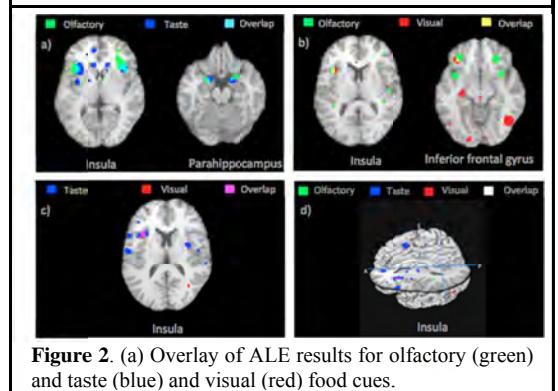


Figure 2. (a) Overlay of ALE results for olfactory (green) and taste (blue) food cues. (b) Overlay of ALE results for olfactory (green) and visual (red) food cues. (c) Overlay of ALE results for taste (blue) and visual (red) food cues. (d) 3D surface rendering of the brain showing the overlap of ALE results for olfactory, taste, and visual food cues, with the insula highlighted in purple.