The effect of fat on the cortical response to flavour

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Introduction: Fat affects both the flavour and textural attributes of food products and these attributes contribute to making high fat food products rewarding for the consumer to eat. However, this may lead to over consumption of fat, which is associated with an increased risk of obesity, diabetes and cardiovascular disease. An increased understanding of the impact of fat on the cortical response to flavour could assist in the design of products that are lower in fat but still rewarding to eat. Few studies have assessed the cortical response to fat in humans (1-3), and none have directly assessed the impact of fat on flavour perception. Here we investigate the effect of fat on the flavour perception, using model emulsions to control for volatile release and viscosity whilst modulating fat content.

Materials and Methods: 13 right-handed healthy subjects (8 male, 5 female) took part. The study was approved by the local Research Ethics Committee, and all subjects gave informed written consent.

Paradigm: In an fMRI cycle (**Fig. 1**) 3ml of the following four stimuli were delivered in a random order over a 3s period: (A) *unflavored fat emulsion* - 22% rapeseed oil, but no sugar or volatile mix; (B) *flavored no fat stimulus* - no oil, 10% sucrose and 6.25ml/kg volatile mix (Ethyl Acetate, Isoamyl acetate, Ethyl butyrate, and Benzaldehyde); (C) *flavored fat emulsion iso-release to sample B* - 22% rapeseed oil, 9.43% sucrose, and 13.6ml/kg of volatile mix; (D) *flavored fat sample iso-perceived to sample B*: 22% rapeseed oil, 9.07% sucrose, and 18.63 ml/kg of volatile mix. After each stimulus, two mouth rinses of 3 ml lime juice solution followed by 3ml water were delivered to clean the oral cavity. A visual cue instructed subjects to swallow immediately after each sample delivery. Electromyography (EMG) was recorded concurrently during fMRI to identify the exact time of swallow to accurately model fMRI responses. Nine repeats of each stimulus were acquired in an fMRI scan.

Data Acquisition: Data was acquired on a Philips Achieva 3T scanner using a SENSE head coil. 36 transverse double-gradient-echo (TE 30 and 49 ms), EPI (64x64 matrix, voxel size 4x4x4 mm^3) images were acquired every 2.6 s (jittered) throughout the fMRI paradigm. Following the fMRI experiment a multi-gradient-echo EPI data set (TE 11, 30, 49, 68 and 87 ms) was acquired to form a T_2* map.

Data Analysis: fMRI data was analysed using SPM5 and matlab. Data was corrected for slice timing, and realigned. T_2* maps were then calculated from the multi-echo data, and used to perform a weighted summation [4] of the two echoes of the BOLD fMRI data. The weighted fMRI data were then normalised to MNI space and spatially smoothed with an 8 mm Gaussian kernel. Global scaling and temporal filtering with 80 s high pass filter cut-off were applied. A general linear model was formed for each subject to identify the cortical response to stimulus A, B, C and D. Each stimulus was modelled as a box function convolved with a canonical HRF. The duration of the box was determined from the stimulus delivery plus the actual time of each swallow as determined from the EMG trace. Individual motion parameters and the two mouth rinse events were included as covariates of no interest. A random effects (RFX) group analysis was performed to determine the brain areas activated in response to each stimulus. Paired t-test contrasts were then performed to assess areas with a differential response to flavour alone vs fat alone (B vs.A), flavoured fat vs flavoured no fat emulsions matched for volatile release (B vs.C) or flavour perception (B vs.D), and finally iso-release v iso-perceived flavoured fat emulsions (C vs.D). To quantify differences in stimuli, an ROI analysis was performed on anatomically defined areas: anterior, mid and posterior insula, SI mouth and SII, thalamus and amygdala (defined from the PickAtlas);anterior cingulate, and OFC defined from de Araujo [1]. For each ROI and each stimulus, the mean top 5% of T-score was assessed.

Results: Activation maps of the main effect of A, B, C and D stimuli showed similar activation patterns in the area of interest including anterior, mid and posterior insula, somatosensory cortices (SI and SII), anterior cingulate (AC), thalamus, and amygdala, **Fig2.** ROI Analysis (**Fig 3**) indicated that the presence of flavour results in increased cortical response across all brain areas. Despite B and C being iso-aroma release, C had a significantly suppressed cortical response (B>C) in primary taste areas (anterior insula), oral somatosensory areas (mid and posterior insula, and SII), and reward areas (anterior cingulate). Despite B and D being iso-perceived, D had a significantly suppressed cortical response (B>D) in mid insula, SI, amygdala, and anterior cingulate. D resulted in significantly greater response in anterior/posterior insula compared to C which may be accounted for by the fact D has increased flavouring stimuli at the receptors, although in terms of fruitiness perception no difference was detected.

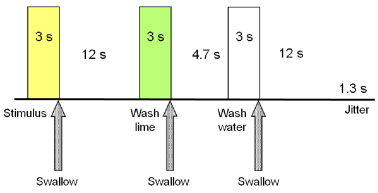

Fig.1: One cycle of fMRI paradigm

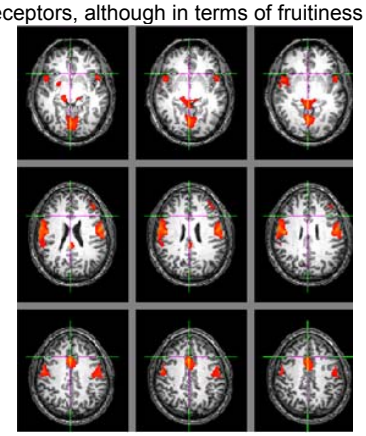

Fig.2: Axial slices of RFX maps for stimulus B, FWE <0.05

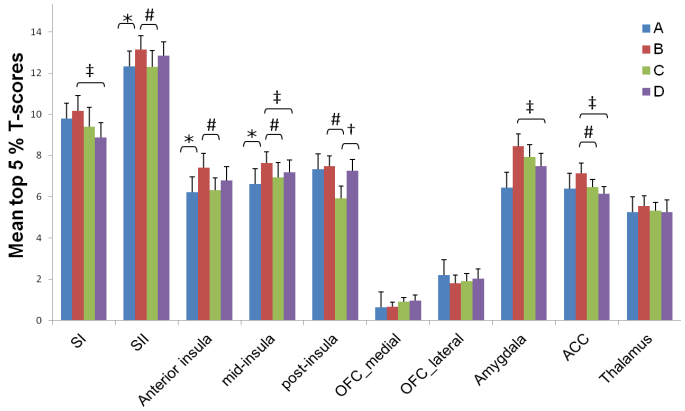

Fig.3: ROI comparing cortical response to samples A-D. a significant difference is represented by * for B vs A, # for B vs C, ‡ for B vs D, and † for C vs D.

Discussion: In this study, we mapped the cortical representation to no flavoured fat, flavoured no fat, iso-release and iso-perceived flavoured fat emulsions. Activations in the primary taste areas, oral somatosensory, thalamus and reward areas in response to no flavoured fat emulsions are consistent with areas previously reported to fat emulsions [3]. Activations in ACC and amygdala (reward areas) in response to oral fat stimuli have been also reported by other studies [1,2]. We showed that the presence of fat in the oral cavity reduces the cortical response to flavour (particularly in the primary taste areas and anterior cingulate) even when samples are iso-perceived (and have the same volatile release) for sweetness, flavour and thickness. **References:** [1] de Araujo, I. E. and E. T. Rolls (2004), J. Neurosci. **24**: 3086-3093. [2] Grabenhorst, F. et al. (2010), Cereb. Cortex **20**: 1082-1091.[3] Eldeghaidy, S. et al. (2011), J Neurophysiol **105**: 2572-81. [4] Posse, S et al (1999), MRM **42**:87-97.

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