The cortical representation of taster status: reducing the heterogeneity of group fMRI

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Introduction: fMRI data is typically used to study the response of the general population, however the power of the response will be limited due to heterogeneity in the general population. Subdividing the population on the basis of known normal phenotypes will both improve the sensitivity of the group analysis and provide new information about phenotypical behaviours. Here we assess the effect of taster status on the fMRI response to fat. Individuals experience different intensities and liking of fat-containing substances, dependent on their taster status (TS), with 'supertasters' (ST) being most sensitive to fat content [1]. Taster status is genetic in origin, and is thought to be mediated by sensory responses reflecting individual differences in the density of fungiform papillae on the tongue, however the sensory basis of taster status has not been validated in the cortex [2].

Materials and Methods: Subjects**:** 14 right-handed healthy subjects took part in the study which was approved by the local Research Ethics Committee.

Paradigm: An automated stimulus delivery spray system [3] was used to deliver a fat emulsion to the tongue and oral cavity. The emulsions were iso-viscous and underwent full psychophysical characterisation. In each fMRI cycle 3 ml of 5%, 10%, 20% or 30% oil fat emulsion was delivered in random order over a 3 s period. After each stimulus 2 mouth rinses were delivered to clean the oral cavity, 3 ml lime juice solution followed by 3 ml of water. A small visual cue instructed the subjects to swallow immediately after each sample delivery. Electromyography (EMG) was recorded concurrently during fMRI acquisition to monitor and identifiy the exact time of swallow to accurately model the fMRI responses. 9 cycles at each fat level were acquired.

Behaviour testing: Following the scanning session subjects ranked the four emulsion samples in order of preferences. To assess taster status, subjects rated the bitterness intensity of a PROP solution on a Generalised Labelled Magnitude Scale (gLMS) [4] and were classified as a 'super-taster (ST)' (>40), 'medium-taster (MT)' (20–40) or 'non-taster (NT)' (<20).

fMRI Acquisition and Analysis: Data was acquired on a Philips Achieva 3T scanner using a SENSE head coil. 36 transverse double-gradient-echo (TEs of 30 and 49 ms), EPI (64x64 matrix, voxel size 4x4x4 mm^3) images were acquired every 2.6 s (jittered). Following the fMRI experiment a multi-gradient-echo EPI data set (TE's: 11, 30, 49, 68 and 87 ms) was acquired to form a T_2* map. FMRI data was analysed in SPM5 and was corrected for slice timing and realigned. T_2* maps were used to perform a weighted summation [5] of the two echoes of the fMRI data. The combined weighted fMRI data were normalised to the standard EPI template and spatially smoothed with a 12 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 cortical activation to oral fat by modelling the stimulus as a box function convolved with a canonical HRF. The length of the box function of the fat delivery was defined from EMG, individual motion parameters and the mouth rinse events were included as covariates of no interest. A random effects group (RFX) analysis was performed. To assess correlation of taster status with brain activity, anatomically defined ROIs (defined by the PickAtlas [6]) were formed in: SI mouth and SII; insula (subdivided into mid-, anterior and posterior portions); anterior cingulate, thalamus and amygdala, and lateral [26,32,-10] and medial [-6,44,-2] OFC defined from de Araujo [7]. For each ROI, the maximum T-score was assessed and any significant differences between the maximum T-scores between ST, MT, NT groups tested.

Results: The preference test showed the 30 and 20 % emulsions were significantly preferred to 10 and 5 % emulsions (P <0.05), all STs ranked the emulsions in order of fat concentrations for preference (30 % fat most preferred) whilst MT and NT showed no consistent preference ranking. The random group analysis revealed areas activated for oral fat (**Fig. 1**) in: (a) taste areas including bilateral frontal opercular and R anterior insula, (b) areas associated with intraoral somatosensory textural attributes of fat (post- pre-central gyrus, and superior parietal cortex), (c) areas that represent hedonic properties of the fat including bilateral dorsolateral prefrontal cortex, R thalamus and R amygdala. Results from ROIs analyses showed that T-scores in SI, SII, mid- and posterior insula, amygdala and anterior cingulate in both R and L hemispheres increased significantly with taster status (ST> MT >NT),with a trend for increase in anterior insula and lateral OFC with TS (**Fig. 2**). On post-hoc group analysis, SI, SII, posterior insula, ACC and the amygdala showed a significant difference between each TS group (ST, MT, NT). In the anterior insula no significant difference was found between T-scores for STs and MTs, however (ST>NT and MT>NT) differences were significant.

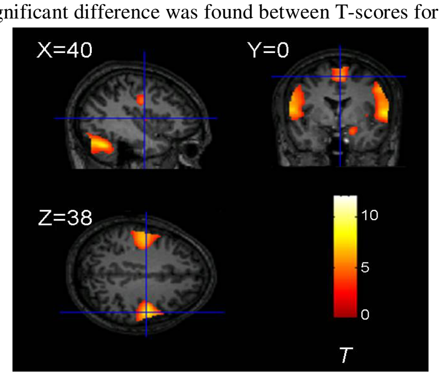

Fig. 1 *RFX map (uncorrected P<0.001)*

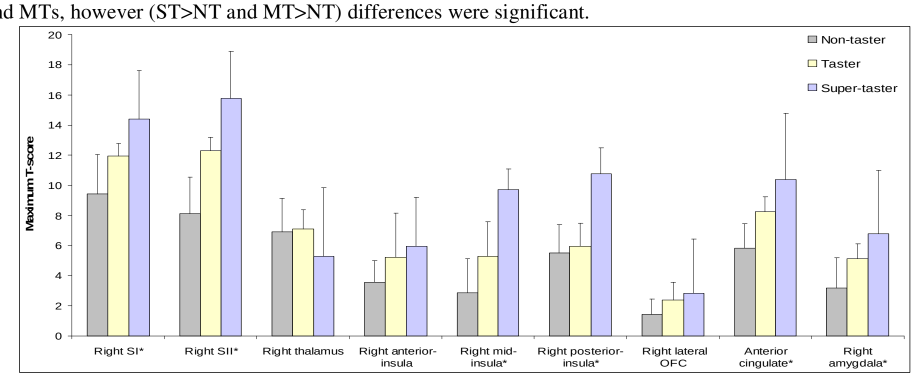

Fig. 2: *Mean maximum T-scores for ROIs for NTs, MTs and STs. * indicates those regions with significant differences (P <0.01) between groups.*

Discussion: We have mapped the cortical representation of taste for different taster populations using iso-viscous oral fat emulsions. Taster status (ST>MT>NT) is highly correlated to the cortical response in somatosensory areas (SI, SII, mid- and posterior insula), and reward areas (amygdala and anterior cingulate) but not significantly in the classical primary taste area of the anterior insula, supporting the theory of increased sensory innervation in supertasters [2] and the increased liking of fat [1]. The inter-individual differences in BOLD amplitude with taster status show that the variance in the BOLD response can be improved by selecting subjects with a particular taster status for group analysis, with supertasters improving detection power.

References: [1] Yackinous C, Guinard JX (2001) Physiol & Behav 72:427-37. [2] Essick GK, et al (2003) Physiol Behav 80:289-302. [3] Marciani L et al (2006) J Neurosci Methods 158:186–94. [4] Bartoshuk, LM. (2000) Appe 34:105. [5] Posse S et al (1999) MRM 42:87-97. Maldjian JA, et al (2003) Neuroimage 19:1233-39. [7] de Araujo IE, et al (2004) J Neurosci 24:3086-93. **Acknowledgements:** This work was funded by the BBSRC and Unilever.