Cortical response to oral viscosity

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Background:

Meal viscosity is important in determining the sense of satiety [1,2]. However, it is not clear to what extent this effect is due to sensations in the mouth or stretch receptors in the stomach. fMRI potentially provides an objective method of studying both the immediate response to oral viscosity and the long term response to meal viscosity. The insular/opercular primary taste cortex [3] and the orbito-frontal cortex [4] of non-human primates have been shown to represent food viscosity, and recently a similar insular representation for intra-oral viscosity has been found in humans using fMRI [5].

Aim:

To determine the cortical areas responding to meal viscosity, using techniques with wider brain coverage and improved sensitivity in the frontal lobes compared to previous studies.

Methods:

Subjects: 7 male and 3 female healthy subjects, 25-36 yrs, right handed and with no history of neurological disorders participated, without having fasted. Data from 2 additional subjects were discarded, one due to equipment failure and one due to coughing leading to large head motion. This study was approved by the local Ethics Committee, and all subjects gave informed, written consent. **MRI methods:** A 3.0T purpose-built scanner was used with a TEM head coil and an inset head gradient coil. After acquisition of a 64 slice EPI set, the activation experiment was performed. 26 contiguous, multi-gradient-echo, EPI, coronal 5 mm thick slices were acquired from 64 to -66 MNI anterioposterior co-ordinate units (frontal gyrus to the lateral ventricles), with a volume repetition time of 2.6 s (jittered). Following each RF pulse, a double EPI acquisition was made with TEs of 22 ms and 39 ms (1.9 kHz gradient switching frequency, in-plane resolution 4 mm x 4 mm, 64 x 64 matrix). The blipped gradient was 'wound-back' in k-space between trajectories so that the 2 echoes had similar sensitivities to distortion. The high switching frequency, multi-echo acquistion and relatively thin coronal imaging minimised spatial distortion and improved sensitivity in frontal lobes. At the end of the activation experiment a T_2* map of the same 26 coronal slices was formed by acquiring 4 EPI images per pulse at TEs of 22, 39, 56 and 73 ms. **Paradigm:** The paradigm used is illustrated in **Fig. 1**. We manually delivered 4 ml of a viscous stimulus (a 1.25% manugel alginate solution) or of a control (water) stimulus (randomly ordered) using syringes and small plastic tubes held between the lips of the supine subject. Between each stimulus the subjects were given 5 ml water to rinse the mouth using a pump. **Analysis:** Data were realigned and resliced using SPM2 (all motion < 1 pixel). T_2* maps were calculated from the 4-echo data using a weighted least squares fit, enabling a weighted summation [6] of the 2 echoes from the fMRI time course. The data were then spatially normalised to the standard template, spatially smoothed (8 mm FWHM) and high pass filtered (128 s cutoff) in SPM2. The stimulus was modelled as a box of 3 s length convolved with a canonical HRF (no temporal derivatives). The individual motion parameters and the mouth rinses (convolved with the HRF) were included as covariates of no interest for every subject. After evaluating the individual statistical parametric maps, a fixed effects group analysis was carried out to determine any differences between the effects of the viscous stimulus and control. Reported p values were controlled for false discovery rate [7]. Conservative small volume correction [8] was applied using a loose mask ($p<0.001$) based on all regions showing a response to both the stimulus and control combined.

Results:

Activation due to the difference in viscous and control stimulus was detected in the right parietal operculum ($p=0.023$ FDR corrected, at 54 -28 42 MNI co-ordinates, fig. 2a) and left insular ($p=0.046$ FDR corrected, at -34 2 10, fig. 2b). There was also a trend for bilateral activation in the parietal lobe (uncorrected p values <0.001, $p=0.84$ FDR corrected, at 38 -38 38).

Discussion:

We have found a BOLD response to viscosity in a mid insular region. A similar BOLD response has recently been reported in the anterior insular (primary taste cortex) [5] and mid insular region (possibly a higher order somatosensory area of the insular), and viscosity sensitive neurones have previously been found in the primary taste cortex of non-human primates. However by extending the scanning volume posteriorly we have also found a differential response to viscosity in the parietal operculum, the somatosensory area representing the mouth, and a trend for activation in the parietal somatosensory association area. In contrast to the results from non-human primates [4], no activation was found in the OFC either in the previous human fMRI study [5] or in this study which used imaging techniques particularly designed to overcome susceptibility artefacts in the frontal lobes. Further work will investigate the factors influencing the response to intraoral viscosity.

Acknowledgements: Funded by Unilever BBSRC Case studentship and MRC.

References: 1. Hoad, C.L., et al., J Nutrition (2004) 134:2293-2300. **2.** Marciani, L., et al., Am J Physiol (2001) 280:G1227-G1233. **3.** Verhagen, J.V., et al., J Neurophysiol (2004) 92:1685-1699. **4.** Rolls, E.T., et al., J Neurophysiol (2003) 90:3711-3724. **5.** de Araujo, I.E. and E.T. Rolls, J Neurosci (2004) 24:3086-3093. **6.** Posse, S., et al., MRM (1999) 42:87-97. **7.** Genovese, C.R., et al., Neuroimage (2002) 15:870-878. **8.** Worsley, K.J., et al., Human Brain Mapping (1996) 4:58-73.

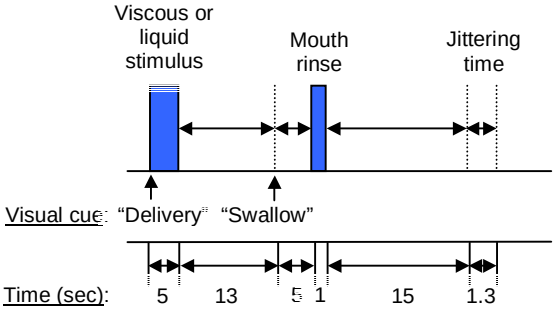

Figure 1

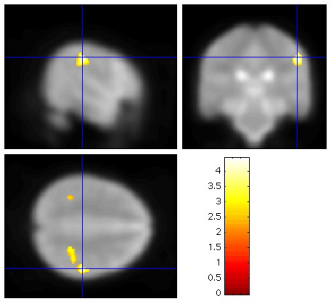

Figure 2a

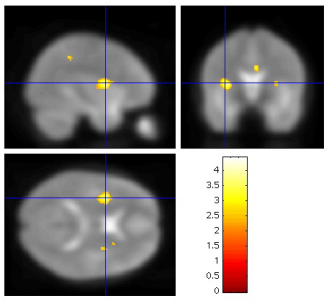

Figure 2b

Fig. 1: The volunteers were exposed to the stimulus for 5 seconds. They were asked to minimise tongue movements and keep the meal in the mouth for the following 13 seconds, after which they were visually cued to swallow. (**b**) Five seconds after the visual swallow cue, 5 ml of water were delivered to rinse the mouth over 1 sec. This was swallowed immediately without visual cue. 10 cycles were acquired for each subject. **Fig. 2:** The (uncorrected $p<0.01$) activation detected in **(a)** the right parietal operculum and **(b)** the left insular regions. Fig 2 a also shows the parietal area in which there was a trend for activation.