fMRI of taste and aroma associations

S. F. Eldeghaidy[1], L. Marciani[1,2], J. Pfeiffer[3], K. Head[1], J. Hort[3], A. J. Taylor[3], R. C. Spiller[2], P. A. Gowland[1], S. Francis[1]

[1]Sir Peter Mansfield Magnetic Resonance Centre, School of Physics and Astronomy, University of Nottingham, Nottingham, England, United Kingdom, [2]Wolfson Digestive Diseases Centre QMC Hospital, University of Nottingham, Nottingham, England, United Kingdom, [3]Division of Food Sciences, University of Nottingham, Nottingham, England, United Kingdom

Background: We have previously developed improved methods [1] to study the cortical representation of taste and retro-nasal aroma stimuli [2-5] using fMRI with a protocol closer to the normal consumption of liquid foods (including physiological swallowing), larger liquid volumes, a novel automated and reproducible stimulus spray delivery system and EPI techniques with wide brain coverage and improved sensitivity in the frontal lobes. In the eariler development study we were unable to discriminate effectively between the cortical representation of taste/aroma associations and the effects of unimodal taste or aroma since only a single stimulus was delivered which comprised of both a taste and an aroma.

Aim: To build on our previous studies to assess the cortical representation of taste and retro-nasal aroma associations using fMRI with an improved paradigm.

Materials and Methods: Subjects: This study was approved by the local Ethics Committee. Six right-handed healthy subjects (4 male and 2 female) participated after giving written consent. **MRI:** A 3.0T purpose-built scanner was used with TEM head coil and 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 anterio-posterior co-ordinate units, 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 acquisition and relatively thin coronal imaging minimised spatial distortion and improved sensitivity in frontal lobes. Following 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:** We used an automated stimulus delivery system [1] which allows delivery of a spray to the tongue and the oral cavity. In an fMRI cycle (**Fig. 1**) we delivered in random order, over a 3 sec period, 3 ml of one of the following 4 stimuli: (**a**) **taste:** 3% sucrose. (**b**) **aroma** 100ul/l isoamylacetate (which has a banana/pear aroma) and trace amounts of "mock saliva" (trace amounts of KCl and $NaHCO_3$). (**c**) **taste and aroma:** a combination of both 3% sucrose and 100ul/l isoamylacetate. (d) **control**: tasteless solution (only trace amounts of KCl and $NaHCO_3$). After each stimulus we delivered two mouth rinses of 5 ml tasteless solution (each rinse over a 5 sec period) (**mouth rinses**) and a visual cue instructed the subjects to swallow immediately after each delivery. 24 cycles were acquired for each subject. **Analysis:** All data sets were processed using SPM2. T_2* maps were calculated using a pixel by pixel weighted least squares fit and used in a weighted summation [7] of the 2 echoes. The combined weighted data were then spatially normalised to the standard EPI template. 8 mm FWHM spatial smoothing and 128 s high pass filter cut-off were applied. The stimulus was modelled as a box function before the swallow, convolved with a canonical HRF plus temporal derivative. The individual motion parameters and the two mouth rinse events were included as covariates of no interest. A fixed effects group analysis was performed. Areas of activation due to unimodal taste, unimodal aroma and taste and aroma combinations were initially identified. Statistical comparisons were then made between the effect of the combined taste+aroma stimulus and the sum of unimodal taste and unimodal aroma stimuli, to identify areas involved in processing taste and aroma associations. A conservative small volume correction [8] was applied using a mask of regions showing a response to all four stimuli at $p<0.001$. p values were corrected for false discovery rate [9].

Results: A difference between the combination of taste+aroma and the sum of unimodal taste and unimodal aroma was detected in several brain regions. These are summarised in the following table with their corresponding Z-scores, corrected p values and MNI coordinates. An example of activation in the orbitofrontal cortex due to this contrast is shown in **Fig. 2** (overlaid on the SPM2 template with uncorrected $p<0.01$).

COMBINED TASTE+AROMA > UNIMODAL TASTE +UNIMODAL AROMA				Area	Z-score	P	MNI coordinates x, y, z
Area	**Z-score**	**p**	**MNI coordinates x, y, z**	Left frontal operculum	4.60	0.001	-54, 14, -4
Left anterior insula	2.85	0.018	-30, 18, 6	Right frontal operculum	3.64	0.003	50, 10, -4
Right anterior insula	4.23	0.001	34, 22, 2	Left parietal	4.67	0.001	-54, -40, 20
Left mid-posterior insula	2.97	0.014	-40, -6, 10	Orbitofrontal cortex	4.75	0.001	-2, 50, -4
Right mid-posterior insula	3.76	0.002	38, 0, 10	Middle cingulate cortex	4.52	0.001	4, 12, 52
Left DLPFC	4.27	0.001	-22, 32, 38	Piriform	4.40	0.001	-26, -4, -10
Right DLPFC	4.18	0.001	24, 28, 38				

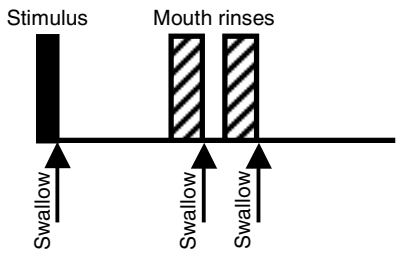

Figure 1

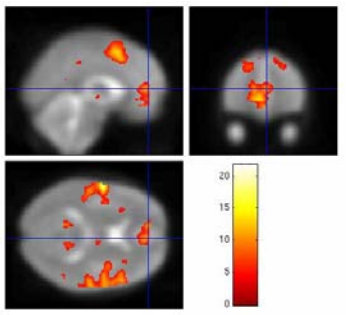

Figure 2

Discussion: We have been able to detect the cortical representation of associations of taste and aroma (versus unimodal taste or unimodal aroma) in a protocol that is closer to the typical experience of consuming liquid foods. This protocol can be combined with subjects' sensory ratings to improve knowledge of the perception of taste, aroma and their interactions [10].

References: 1. Marciani et al (2005), Proceedings 13th ISMRM, Miami 2005, p. 572. **2.** Small DM et al (1999) Neuroreport 10:7-14. **3.** O'Doherty J et al (2001) J Neurophysiol 85:1315-1321. **4.** Cerf-Ducastel B et al (2001) Chem Senses 26:625-637. **5.** O'Doherty J et al (2000) Neuroreport 11:893-897. **6.** de Araujo IET et al (2003) Eur J Neurosci 18:2059-2068. **7.** Posse S et al (1999) MRM 42:87-97. **8.** Worsley KJ et al (1996) Hum Brain Mapp 4:58-73. **9.** Genovese CR et al (2002) Neuroimage 15:870-878. **10.** Cerf-Ducastel B et al (2004) Physiol Behav 81:389-396.