Cortical Processing in Thermal Tasters: Evidence for Cross-modal Integration

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Introduction:

Recent findings have shown that in some subjects, termed 'thermal tasters' (TTs), thermal stimulation of the tongue elicits a phantom taste, whereas in 'thermal non-tasters' (TnTs) this effect is not found [1]. Behavioural studies show that TTs are more sensitive to pure taste stimuli at supra-threshold levels compared to TnTs [2]. Here, we explore the cortical response in TTs and TnTs to a gustatory-trigeminal stimulus to assess the hypothesis of increased interaction of taste and trigeminal nerves in TTs.

Methods:

•***Participants:*** 24 subjects (11 male) took part in the study, 12 TTs and 12 TnTs matched for PROP taster status (4 PROP non-tasters, 6 PROP medium-tasters 2 PROP super-tasters).

•***Thermal Taster Status:*** This was assessed using an intra-oral thermode (Medoc PATHWAY) applied to the anterior tongue tip. Warming and cooling trials were carried out in duplicate [1,2], Fig.1a. If a taste was perceived, subjects were asked to state the taste quality and rate its intensity for each trial on a gLMS.

•***Stimuli and Protocol:*** In an fMRI cycle (Fig.1b), 2 ml of one of three sweet samples with different CO_2 levels (No CO_2, Low CO_2, and High CO_2) was delivered to subjects over a 2 s period.

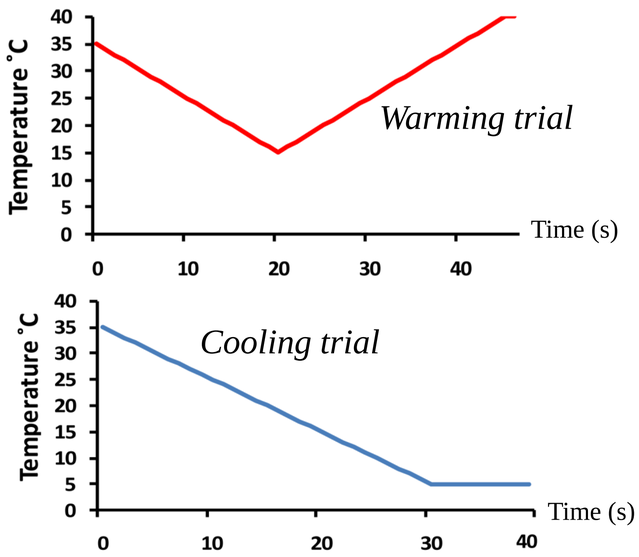


Fig.1a: Thermal stimulation paradigm

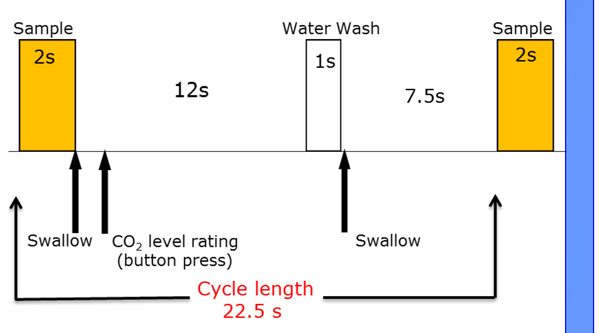


Fig.1b: fMRI protocol

• ***Data Acquisition and Analysis:***

• fMRI data was acquired on a Philips 3T Achieva scanner using 36 transverse dual-echo GE-EPI images (TE: 20/45ms, SENSE 2, 3x3x3 mm^3, TR: 2.5s).

• fMRI data were slice timing corrected and realigned (SPM5). A weighted summation of the dual-echo fMRI data was performed and then normalised to MNI space, spatially and temporally filtered. A GLM analysis was formed for each subject to identify cortical activation to each CO_2 level. Group analysis (RFX) and ROI analysis of parameter estimate (β-values) based on *a priori* areas were performed for each CO_2 level.

• A 1st order parametric modulation was also included in the GLM to identify brain areas showing a correlation with CO_2 level.

Results:

- TTs were significantly more discriminating of the high CO_2 sample than TnTs, with no significant difference for the 'No' and 'Low' CO_2 samples, Fig. 2.

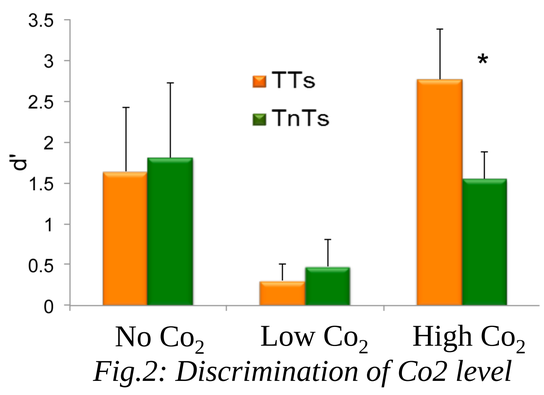


Fig.2: Discrimination of Co2 level

- Activation maps for TTs and TnTs revealed a large network of brain areas in response to all CO_2 levels, with the TT group showing significantly greater cortical activation.
- TTs showed significantly greater BOLD response for the taste only stimulus (No CO_2) in SI, SII, ACC, anterior and posterior insula, compared with TnTs group, Fig. 3.

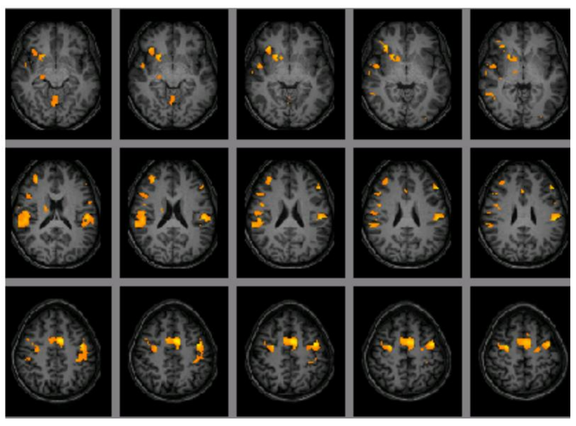
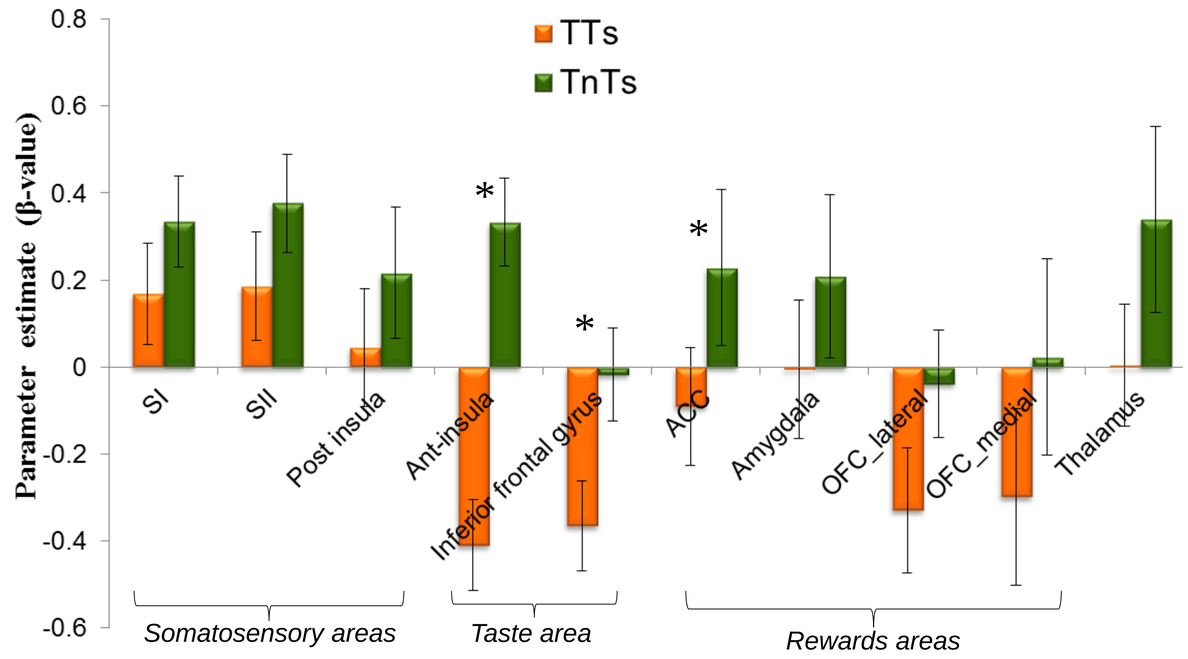


Fig.3: RFX differential activation map (TT > TnT group) for 'No CO_2' sample (taste only), displayed with p<0.01 uncorrected.

- The cortical activity of TTs negatively correlated with CO_2 level in taste (anterior insula, inferior frontal gyrus) and hedonic areas (ACC, OFC) in the TT group, and positively correlated in somatosensory areas (SI, SII, and posterior insula). The TnT group showed a positive correlation in all brain areas, and a negative correlation inferior frontal gyrus, Fig. 4.

(a)



(b)

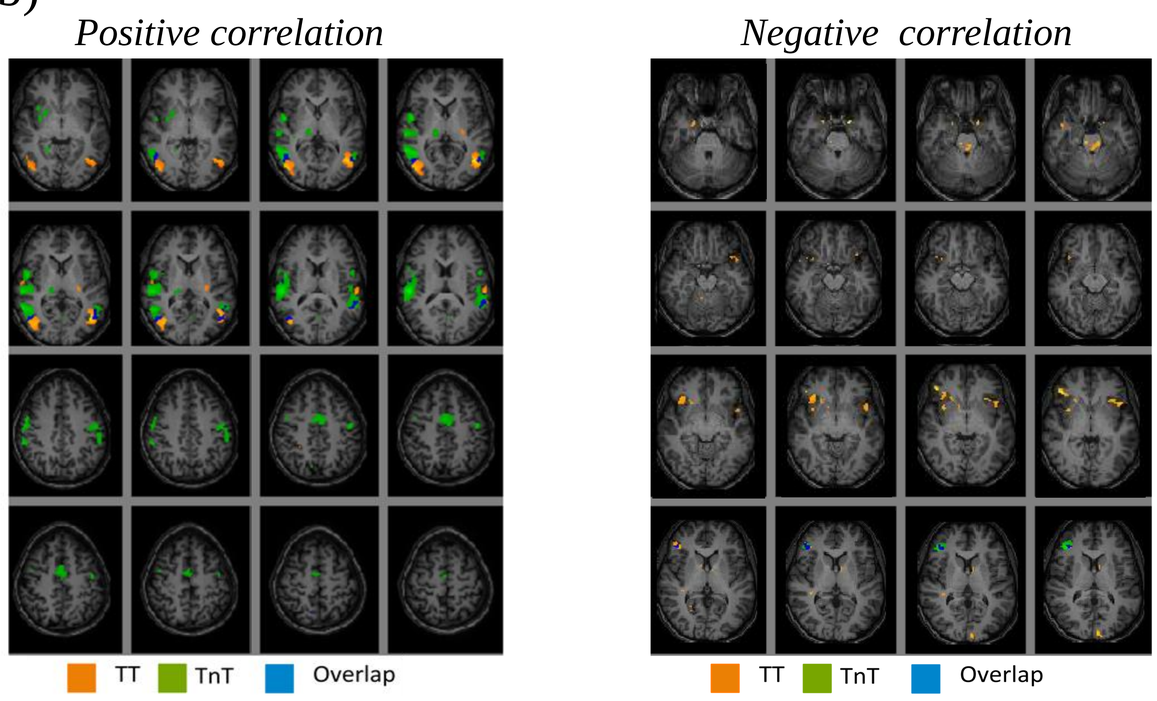


*Fig.4: a) Beta values and b) group activation maps for brain areas correlated with CO_2 level in TTs and TnTs, maps displayed with p<0.05 FDR. * indicates significant difference, p<0.05.*

Discussion:

The cortical activation to gustatory (taste) and a combined taste and trigeminal (CO_2) samples was heightened in TTs compared to TnTs. Although no difference in discrimination of taste sample 'No CO_2', TTs showed a higher cortical activation to 'No CO_2' than TnTs. The addition of trigeminal stimulation led to a much greater cortical activation in somatosensory areas in the TnT group than the TT group. The increased activation in TTs to taste alone, and reduced response to increasing CO_2 levels in this study supports a cross-modal integration mechanism arising from an interaction of taste and trigeminal nerves, even in the absence of CO_2.

References

[1] Cruz, A. and Green, B. G. Nature, 403 (6772): 889-892, 2000.
[2] Bajec, M. R. and Pickering, G. J. Physiology & Behavior, 95 (4), 581:590, 2008.

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