

Caloric and non-caloric versions of a soft drink differentially affect taste activation before consumption

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Introduction

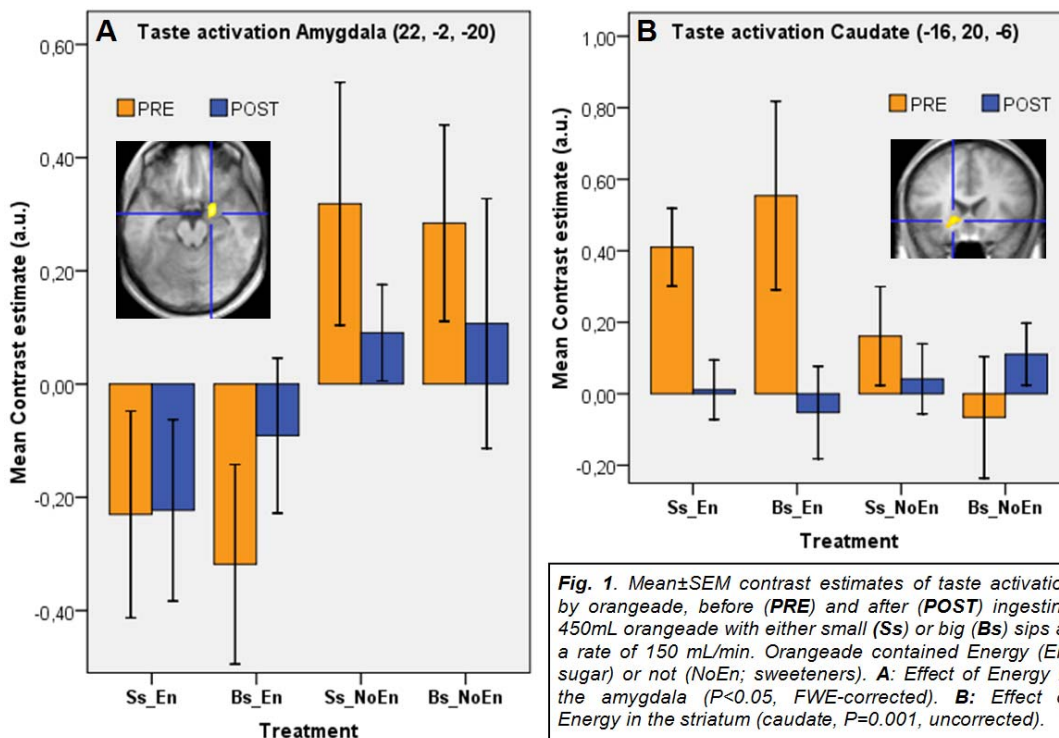
Meal termination is brought about by a combination of sensory satiation, gastric signals of fullness and metabolic satiation (energy repletion). Previously, it has been shown that taste activation in the orbitofrontal cortex (OFC) decreases due to sensory satiation¹. We hypothesize that smaller sips are associated with more sensory stimulation and therefore with greater sensory satiation and a greater decrease in taste activation. In addition, sensory and metabolic satiation could have separate as well as synergistic effects on brain activation. Here, we varied sip size and energy-content of a soft drink and measured the effects of its consumption on the brain activation associated with tasting using functional MRI.

Subjects and methods

Ten healthy, normal-weight, right-handed men participated in a 2x2 randomized single-blind crossover design. Subjects were scanned twice, after fasting for at least 2h and after treatment, on 4 occasions. Treatment consisted of the ingestion of 450mL of orangeade ("Energy", sweetened with 10% sucrose or "No-Energy", sweetened with non-caloric sweeteners), delivered to the mouth by a peristaltic pump at an average rate of 150 mL/min, with either small (5mL) or large (20mL) sips. Orangeades were matched for color and sweetness. The functional scan was a T₂-weighted gradient-echo 3D-EPI sequence (dynamic scan duration = 850 ms, TR/TE = 120/30 ms, flip = 30°, FOV = 208 × 208 mm). In one functional run 1024 scans were made. During scanning, subjects tasted orangeade and two control stimuli (milk and tomato juice) for 10s, followed by a visual cue for swallowing and a rinse with water. After tasting a stimulus, subjects either rated stimulus pleasantness on a 9-point hedonic scale or they received the control condition (tasting without receiving an actual taste; visual cues for tasting and swallowing + rinsing). Before and after every scan session, subjective ratings of pleasantness, prospective consumption, desire to eat and sweetness were given for all three stimuli. Before the first and after the second scan, subjective ratings of hunger and thirst were given. Functional images were preprocessed and analyzed using SPM5. In the first level analyses, contrast images were calculated for all tastes versus the control condition. Using these, effects of treatment on taste activation were assessed for all stimuli with a within-subjects repeated measures ANOVA. A priori regions of interest (ROIs) were the insula, amygdala, striatum (putamen + caudate) and OFC.

Results

The insula was activated to a similar extent by all stimuli, before as well as after treatments (MNI (39, 0, 13), $P < 0.05$, FWE-corrected). Main effects of Energy were found in the amygdala, striatum and inferior temporal gyrus. Before treatment, the amygdala was activated more by No-Energy orangeade than by Energy orangeade (Fig. 1A). In the striatum ROI, Energy orangeade activated the caudate before, but not after treatment (Fig. 1B). The same pattern was found in the inferior temporal gyrus (MNI (46, -4, -34), $P < 0.001$, uncorrected). There were no main effects of sip size on taste activation and no interaction between sip size and energy-content.



Discussion & Conclusion

We found no significant effects of sip size on brain activation. This suggests that 450 mL is not enough to differentiate between the effects of small and large sips on sensory satiation with our sample size. In a preceding related study, we found that smaller sips were associated with decreased ad libitum intake of the same orangeades. However, decreases in pleasantness ratings were similar for both sip sizes (Weijzen P. *et al.*, 2008, *submitted*). The strongest effect of energy content was found in the amygdala, which was more activated by non-caloric orangeade than by caloric orangeade before treatment. After treatment, amygdala activation did no longer differ between the two orangeades. Thus, amygdala activation appears to reflect sensory satiation for the sweet taste of the non-caloric orangeade. It remains to be investigated why the amygdala deactivates in response to an energy-containing drink, while it activates in response to a non-caloric drink.

Before ingestion, the caloric drink elicited stronger striatal activation than the non-caloric drink, which is in line with recent findings². We found that after consumption striatal activation diminished substantially. Combined with the minor activation by sweet taste only, our results suggests that activation of this part of the caudate reflects metabolic, rather than sensory satiation. In conclusion, we found differential activation of brain areas implicated in food intake regulation by caloric and non-caloric versions of a soft drink. Our results show that the brain can distinguish between a caloric and a non-caloric version of a soft drink and suggest that sensory and metabolic satiation differentially affect taste activation. This may have important implications for how effective non-caloric sweeteners are in curtailing sugar intake.

References: [1] Kringelbach M.L. *et al.* *Cereb. Cortex* **13**, 1064-1071 (2003). [2] Frank, G.K. *et al.* *Neuroimage* **39**, 1559-1569 (2008).