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That smells filling: Effects of pairings of odours with sweetness and thickness on odour perception and expected satiety

Martin R. Yeomans *, Sophie Boakes

School of Psychology, University of Sussex, UK

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ABSTRACT

Retronasal co-experience of odours with sweet tastes and thick textures have been shown to result in attribution of sweetness and thickness to odours when they are subsequently sniffed. Orosensory thickness and creaminess are also associated with expectations that a product will be filling. Here we test for the first time whether co-experience of odours with orosensory thickness and sweetness results in transfer of satiety expectations to these odours when subsequently sniffed. Eighty healthy volunteers evaluated the hedonic and sensory characteristics of odours, and expectations that products with the same flavour as the odour would be filling, before and after disguised co-experience of odours with sweetness (sucrose), thickness (tara gum solution) or the combination of sweet/thick, as well as untrained (control) odours. Odours paired with tara gum were subsequently rated as smelling thicker and more creamy, while odours paired with sucrose smelled sweeter. Pairing odours with tara gum increased the expectation that products predicted to have the same flavour as the sniffed odour would be more filling, and this was enhanced by sweetness, while pairing odours with tara-gum increased the expectation that products with that odour would reduce later hunger. Liking for odours paired with sweetness increased, but pairing with thickness alone reduced liking. These data suggest that satiety-consonant sensory characteristics can transfer to associated odours, and that this process is independent of changes in liking. This raises the possibility of using satiety-associated odour cues to manipulate consumer satiety expectations.

1. Introduction

The experience of flavour requires multi-sensory integration of stimuli arising from the simultaneous detection of taste, smell and touch in the mouth when foods and drinks are ingested (Prescott, 2004; Small & Prescott, 2005; Spence, 2013). One consequence of the multisensory nature of flavour is that the oral co-experience of gustatory, olfactory and somatosensory stimuli can alter the way the same olfactory components are experienced when they are subsequently sniffed (i.e. experienced orthonasally). Thus, some of the apparent sensory characteristics of food-related odours (such as perceived sweetness) may actually reflect prior associations between the sensed odours and other orosensory cues such as taste and texture, possibly through activation of associated flavour memory (Stevenson & Boakes, 2003). The original evidence for this phenomenon arose from a series of studies conducted by Stevenson and colleagues in the 1990's, where participants rated the characteristics of odour stimuli before and after repeated disguised pairings of the same odours experienced retronasally alongside sweet and sour tastes (Stevenson, Boakes, & Prescott, 1998; Stevenson, Boakes, & Wilson, 2000a, 2000b; Stevenson, Prescott, & Boakes, 1995). In these studies, odours that had been paired with the sweet taste of sucrose were subsequently rated as smelling sweeter, and likewise odours paired with citric acid were rated as smelling more sour. Subsequent studies in other laboratories have confirmed these findings, and extended the tastes that transfer to odours to include bitter, etc. (e.g. Yeomans, Mobini, Elliman, Walker, & Stevenson, 2006).

As well as odours acquiring taste-like percepts, two studies suggest that pairing odours with textural qualities such as viscosity can lead to the attribution of sensory characteristics such as thickness and creaminess to sniffed (orthonasally sensed) odours. The first study paired odours with low and high fat sweetened and unsweetened milk (Sundqvist, Stevenson, & Bishop, 2006), and reported greater rated odour fattiness when sniffing the odours after having co-experienced the odour retronasally in the milk samples. However, in that study the training stimulus was complex, since milk would provide a combination of taste, odour and somatosensory information. To test more specifically whether an odour could acquire somatosensory characteristics by association

* Corresponding author at: School of Psychology, University of Sussex, Brighton BN1 9QH, UK.
E-mail address: martin@sussex.ac.uk (M.R. Yeomans).

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with a more pure somatosensory experience, a subsequent study (Stevenson & Mahmut, 2011) examined changes in odour perception after the test odours had been paired with a tasteless viscous solution (achieved using the thickening agent carboxy methylcellulose, CMC), or a sweet and thick solution (sucrose + CMC). The rated thickness of the odour which had been paired with the sweet/thick orosensory sensation increased, although pairing an odour with thickness alone did not alter subsequent odour thickness ratings. There was also a non-significant trend for increased perceived creaminess for the odours paired with thick and sweet/thick stimuli, while as would be expected the odours paired with the sweet/thick experience during training were rated as smelling sweeter when sniffed after training. Thus these two studies suggest there is some transfer of somatosensory qualities to odours when tested using the odour-taste learning paradigm.

Repeated consumption of foods and drinks can lead to learned changes in hedonic as well as sensory characteristics of the ingested product when it is encountered again. A number of learning processes underlie the change in liking in particular (see Yeomans, 2006 for review). In the present context, co-experience of novel flavour elements (including odour) with known liked or disliked components (such as a liked sweet or disliked bitter tastes) can lead to enduring transfer of the hedonic response to the novel flavour element, a form of evaluative conditioning (Dickinson & Brown, 2007; Wardle, Mitchell, & Lovibond, 2007). Thus, odours paired with sweet tastes become more liked provided the participant liked the training sweet stimulus (Yeomans, Mobini, Bertenshaw, & Gould, 2009; Yeomans, Prescott, & Gould, 2009; Yeomans et al., 2006), while liking for odours paired with disliked bitter tastes reliably decreases (Yeomans et al., 2006).

However, although liking is a key factor in food choice and intake (see Mela, Frewer, & Trijp, 2006; Yeomans, Blundell, & Lesham, 2004 for reviews), people also develop beliefs about what impact consumption of a product will have on their appetite and thirst (Brunstrom, 2011; Forde, Almiron-Roig, & Brunstrom, 2015). These expectations can influence decisions about portion size selection, and how much of a product is consumed (Brunstrom, Collingwood, & Rogers, 2010; Brunstrom & Shakeshaft, 2009; Wilkinson et al., 2012). Analysis of the key sensory and nutritional aspects of snack products that generate expectations of satiety suggests that the perception of creaminess and thickness may be key sensory features that lead to stronger expectations of how filling a product will be (expected satiation) and how well the product will subsequently suppress hunger (expected satiety: McCrickerd, Lensing, & Yeomans, 2015). These findings, based on ratings of expectations from viewing pictures of foods, are further supported by the observation that varying the viscosity of drinks, using thickening agents like tara gum, modify ratings of expected satiation and satiety, even when the perceived differences in thickness are relatively subtle (McCrickerd, Chambers, Brunstrom, & Yeomans, 2012). These creaminess satiety cues are not limited to effects of viscosity alone: altering the size of oil particles in oil-water emulsions also modify satiety expectations. In this context, rated creaminess and thickness, and expected satiation and satiety, all increase as oil droplet size decreases (Lett, Yeomans, Norton, & Norton, 2015). Critically, the expectations generated by these subtle differences in somatosensory experience may be key in determining actual satiety responses to ingested nutrients (see Chambers, McCrickerd, & Yeomans, 2015 for recent review).

Given the clear evidence that orosensory experience of thickness or creaminess can generate expected satiety, and that pairing odours with the orosensory experience of thickness can lead to attribution of creaminess to the associated odours when sniffed (Stevenson & Mahmut, 2011), an intriguing question is then whether repeated co-experience of odours with thickness leads to attribution of increased expectations that products with the thickness-associated odour will be more filling. Expectations about how satiating a product will be are likely to be learned responses (Forde et al., 2015): evaluations of expected satiety depend on familiarity with the rated food (Brunstrom, Shakeshaft, & Scott-Samuel, 2008; Irvine, Brunstrom, Gee, & Rogers, 2013) and can change in line with ingested nutrient content following repeated exposure (Wilkinson & Brunstrom, 2009; Yeomans, McCrickerd, Brunstrom, & Chambers, 2014). Thus the idea that these expectations can be learned is reasonably well established: the idea that these expectations can transfer through orosensory associations alone without ingestion is however untested, and was the primary purpose of the study reported here.

In the present study, participants evaluated the sensory and hedonic characteristics of target odours, as well as ratings of expectations of how filling and hunger-suppressing products with the flavour predicted by these odours would be, when the odours were sniffed. They completed these ratings both before and after a disguised training session where the same odours were experienced in the mouth paired either with sweetness alone (Sweet: 10% sucrose), thickness alone (Thick: a tara-gum solution) or these two combined (Sweet/Thick). The basic design was thus similar to that used by Stevenson and Mahmut (2011): the critical differences were the inclusion of an odour-sweet pairing during the training phase and evaluations of expected satiation and satiety. In line with Stevenson and Mahmut (2011), we predicted an increase in creaminess and thickness ratings for odours which had been co-experienced with thickness in the mouth. We also predicted an increase in sweetness for odours co-experienced with sucrose in the mouth, in line with several earlier studies (Stevenson et al., 1995, 1998; Yeomans et al., 2006; Yeomans, Prescott, et al., 2009). Based on our finding that thickness and creaminess is associated with stronger expectations of satiety, whereas sweetness was not expected to be satiating (McCrickerd et al., 2015), we also predicted that associations with thickness would enhance the degree to which odours modified expected satiation (i.e. the immediate effects of consumption on fullness) and expected satiety (the suppression of hunger post-ingestion) based on anticipation of consuming a beverage with the thickness-associated trained odours.

2. Method

2.1. Study design

The study used a within-subject experimental design to contrast changes in the retronasal evaluations of three odours that had been specifically paired in the mouth with either a sweet taste (Sweet), a viscous solution (Thick) or a combination of these experiences (Sweet/Thick). Two additional odours were evaluated before and after the training session but were not experienced in the mouth, and acted as exposure controls. Since individual differences in hedonic evaluation of the three training conditions could have affected the outcome, sensory and hedonic evaluations of the Sweet, Thick and Sweet/Thick stimuli without any added odours were made after completion of the main part of the study to assess this.

2.2. Participants

Eighty healthy volunteers, 68 women and 12 men, aged 19–36 were recruited from staff and students at University of Sussex. Since the study involved tasting solutions and smelling food-related odours, potential participants who were diabetic,