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Sweet odours and sweet tastes are conflated in memory

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ABSTRACT

Certain odours and certain tastes appear to share common perceptual properties. One example is sweetness, a perceptual experience that results from stimulation of taste receptors on the tongue typically by sugars. The experiment here examined for evidence of this perceptual similarity using a novel and indirect test. Participants were exposed six times each, to three odours (strawberry, caramel, and oregano) and three tastes (sucrose, saline, and citric acid). Following a 10-min interval, participants were given a surprise frequency estimation task, in which they had to judge how often each stimulus had occurred. If sweet-smelling strawberry and caramel odours really do share this perceptual characteristic in common with sweet tasting sucrose, then frequency estimates for sucrose should be overestimated relative to non-sweet tastes. Not only was this observed, but frequency estimates for sweet tastes were also found to correlate with (1) evaluations from a later test of similarity between these sweet smells and sucrose, and (2) the degree to which these odours smelled sweet. These findings suggest a shared perceptual feature between such odours and sucrose – sweetness – under conditions where no judgment of perceptual quality was required.

1. Introduction

Certain odours are commonly reported by participants to smell sweet (Dravnieks, 1985), yet sweetness is a sensation that is typically associated with stimulation of a different sensory system, taste (Schiffman, 2002). The sweet sensation that is perceived when certain odours are smelled does not appear to be produced by inadvertent stimulation of the taste receptors in the mouth, nor by the presence of taste receptors in the nose (Labbe, Damevin, Vaccher, Morgenegg, & Martin, 2006). Rather odour sweetness appears to be learned, in that repeated exposure by mouth to sweet tastes combined with odourants that reach the nose via the nasopharynx (rather than the nostrils – orthonasally) results in learning of the combination, and this combination is then retrieved when that odour is later smelled alone (Stevenson, Boakes, & Prescott, 1998; Yeomans, Mobini, Elliman, Walker, & Stevenson, 2006). A question of some importance, in relationship to such findings, is whether or not the sensation generated by odours that are reported to smell sweet is actually akin to the sensation of sweetness produced by placing certain tastants such as sucrose on the tongue. The present study employed a new and indirect technique to establish whether or not these two forms of sensation are indeed similar.

Certain odours produce a sensation that appears similar to tasted sweetness. This was first noted phenomenologically, in that participants spontaneously used the term sweet to describe such smells (e.g. strawberry; Harper, Land, Griffiths, & Bate-Smith, 1968). The first empirical studies of this phenomenon tested whether combining a sweet-smelling odour with a sweet taste, and presenting this mixture to the mouth, would result in larger sweetness ratings – sweetness enhancement – relative to presenting the sweet taste alone (Frank & Byram, 1988). Such a synergy between a sweet taste and a sweet smell would suggest that both generated similar sensations, and the finding that odour sweetness was able to predict, independently of other variables, the degree to which that odour would demonstrate sweetness enhancement provided further confirmation (e.g. Valentin, Chrea, & Nguyen, 2006). A significant complication with this line of reasoning was the discovery that the number of rating scales that participants completed when evaluating an odour-taste mixture had a big impact upon whether or not 'sweetness enhancement' was observed (e.g. Clark & Lawless, 1994). Multiple relevant scales, such as getting participants to rate strawberry and sweetness when evaluating a sucrose-strawberry mixture were found to reduce or even eliminate the sweetness enhancement effect (van der Klaauw & Frank, 1996).

Such concerns led investigators to contemplate other methods to investigate the putative perceptual similarity between certain tastes and smells. One approach was to see whether sweet smells selectively facilitate the identification of sweet tastes, which they do (White & Prescott, 2007). However, the principal approach adopted to bypass concerns about the use of rating scales has been to

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examine whether sub-threshold sweet smells might be detected more readily in the presence of a sweet taste relative to a non-sweet taste. At least two studies obtained evidence consistent with this (Dalton, Doolittle, Nagata, & Breslin, 2000; Delwiche & Heffelfinger, 2005). The inference from these studies is that the perceptual similarity between the two stimuli is the key factor in promoting sub-threshold detection. However, at least two published studies have not obtained convincing evidence for this effect (Elgart & Marks, 2006; Pfeiffer, Hollowood, Hort, & Taylor, 2005), and a further rather different approach has also cast some doubt over the conclusion of such findings. Rankin and Marks (2000) established whether sweet-smelling odours and sweet tastes form a common judgmental context. Although similarity ratings suggested that participants did indeed judge certain odours and tastes as alike, such odours failed to provide a common judgmental context for sweet tastes. This failure to observe a common judgmental context is perhaps surprising, especially as sweet odours and sweet tastes appear to depend upon overlapping neural structures (i.e. both are adversely impacted by damage to brain structures responsible for taste processing; Stevenson, Miller, & Thayer, 2007) and both sweet-smelling odours and sweet tastes selectively exert common physiological effects (increasing pain tolerance; Prescott & Wilkie, 2007).

In the study reported here we utilized a new technique to explore the perceptual similarity between certain tastes and smells. It has been known for some time that similarity between items or events can later affect judgments of the frequency with which those items or events are believed to have occurred (Conrad, Brown, & Cashman, 1998; Hintzman, 2001). In particular, the greater the similarity between two or more items the more likely it is that this will result in higher frequency estimates for those particular stimuli, relative to their actual rate of occurrence (Jones & Heit, 1993; Tussing & Greene, 1999). On this basis we reasoned that frequency estimates could serve as an indirect means of measuring perceptual similarity without introducing any overt judgments of odour or taste qualities, or indeed, of similarity. Consequently, in the study described below, we exposed participants to sets of tastes, including sweet tastes, and sets of smells, including sweet smells, which were later followed by a surprise frequency estimation task. A surprise task has the added advantage that it tends to draw upon more global features (i.e. those likely to be most salient during perception) rather than on specific local features (e.g. Freund & Hasher, 1989). The frequency estimation task was then followed by a series of tests that included explicit judgments of the perceptual and hedonic qualities of the target odours, and the similarity between these odours and sucrose. We predicted that sweet tastes, and sweet smells, would be judged, incorrectly, to have occurred more frequently than they actually had, and more frequently than non-sweet smells and tastes, which in actuality had all occurred with equal frequency. Furthermore, we expected that the greater the degree of judged similarity between the sweet taste and the sweet smells (and the degree to which these odours smelled sweet) would be associated with higher frequency ratings for the sweet taste.

2. Method

2.1. Participants

Forty-four participants (11 male, 33 female) participated for course credit. One participant was excluded, as her English ability was inadequate to understand the experimental instructions and tasks. The remaining 43 participants had a mean age of 21.0 years (SD = 6.1).

2.2. Stimuli

Three odourants were employed, each dissolved in 10 ml of propylene glycol and then diluted with tap water (as used throughout) to their requisite concentration; caramel (1.0 g/L; Dragoco), strawberry (1.2 g/L; Quest) and oregano (0.5 g/L). Odours were presented in 10 ml aliquots in disposable clear plastic sample cups. All odour solutions were transparent and visually identical.

The three tastants employed were sucrose (5.8% w/v), saline (0.45% w/v) and citric acid (0.2% w/v). Tastants were presented in 10 ml aliquots in disposable clear plastic sample cups (i.e. the same cups and sample size as for the odourants). Tastant solutions were also transparent and visually indistinguishable. Finally, all stimuli were presented at room temperature.

2.3. Procedure

Using a within-participant design, each subject completed a four-phase procedure – exposure to tastants and odourants, the filler task, the frequency estimation task, and the odour/taste evaluations. The first phase involved exposure to two blocks of odourants and to two blocks of tastants. An odour block consisted of 12 samples to smell, and always contained three samples of caramel, three of strawberry, three of oregano and three of water. A taste block consisted of 12 samples to taste, and these always included three samples of sucrose, three of saline, three of citric acid and three of water. Order of presentation within each block was randomized. By the end of the exposure phase participants had sampled (smelled or tasted) 48 stimuli – 6 caramel, 6 strawberry, 6 oregano, 6 sucrose, 6 saline, 6 citric acid and 12 water blanks.

On odour blocks, the experimenter instructed the participant to pick up a sample, sniff it, and replace the cup on the tray and then to judge whether or not the fluid had an odour. The experimenter then enforced a 15 s break before the next sniffing trial began. On taste blocks, participants were instructed to pick up the cup, pour all of the solution into their mouth, roll it around, and then expectorate. Participants were then asked to judge whether or not the solution had a taste. This was followed by a tap water rinse and expectoration. After a 15 s break, the next tasting trial then began. Order of block presentation was fully counterbalanced and participants received a 2 min break between each block.

After the exposure phase was complete, participants were presented with a word finder puzzle and were told that they needed to identify as many words as possible and that this task would be timed. Participants were given 10 min in which to complete as much of the puzzle as possible. As these puzzles were large and complex, no participant identified all the words within the allotted period. The purpose of this filler phase was to ensure that the frequency estimation task drew upon long-term rather than immediate memory. The word finder task was used to minimize the possibility that participants might rehearse information about the exposure phase during this interval.

The frequency estimation task then followed. Each participant completed two such tasks, one for the odours and another for the tastes. The test was a surprise, as no mention was made prior to this point that participants might be asked any questions concerning the exposure phase. Whether the odour or taste frequency estimation task came first or second, was counterbalanced across participants. For the odour task the following instructions were presented: "Earlier, you were given some fluids to smell. Some of these smelled fruity (strawberry odour), some like caramel (caramel odour), some spicy (oregano odour), and some had no smell at all. We would like you now to try and estimate (or guess) how many times you smelled the strawberry, caramel and oregano smelling fluids." Three questions then followed (in a randomized order). One asked participants how many times they had encountered strawberry odour. Another, how many times they had encountered caramel odour, and a final one how many times they had encountered oregano odour. Underneath each question was a scale numbered consecutively from 0 to 24. Participants were