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Olfactory Specific Satiety depends on degree of association between odour and food

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ABSTRACT

The pleasantness of a food odour decreases when that food is eaten to satiety or even smelled for a brief period (Olfactory Specific Satiety, OSS), which suggests that odours signal food variety and encourage approach behaviour toward novel foods. In the study here, we aimed to extend this theory to understand the consequence of manipulating the food consumed and its degree of association to the evaluated odour. We also wished to clarify if these effects related to individual sensitivity to the target odour. In the study here, participants (n = 94) rated the pleasantness of a food odour (*isoamyl acetate*) and then consumed confectionary that had either Low or High association to that odour or a No food control. This was followed by final pleasantness ratings for the odour and a threshold sensitivity test. Results revealed that in line with OSS, pleasantness decreased in the High association group only. This effect was not dependent on any differences in sensitivity to the target odour. These findings are consistent with OSS, and that this effect likely depends on activation of brain areas related to odour hedonics rather than the degree to which the odour is detected.

1. Introduction

Globally, the number of individuals classified as obese has increased dramatically over the years (Ng et al., 2014) and make it imperative that we understand more about the basic mechanisms regulating eating. An important part of this endeavour, is to delineate what drives satiety. One such theory, Sensory Specific Satiety (SSS) (B. J. Rolls, Rolls, Rowe, & Sweeney, 1981), is described as the reduced pleasantness for a food eaten to satiety, compared to foods not consumed. For instance, though we might find potato chips very pleasant at the start of a meal; when we have eaten an entire meal of such food to satiety, we no longer find them to be as pleasant; whereas the pleasantness for say bacon (example of an uneaten food) remains unchanged. Importantly, this effect is not dependent on the energy content of the food consumed (Bell, Roe, & Rolls, 2003). This theory helps explain our propensity for food variety seeking and why we might easily over consume in situations when confronted with a wide selection of food items, e.g. a 'buffet' style meal.

In later work, the researchers examined whether similar effects might be observed for the respective food odour (E. T. Rolls & Rolls, 1997). In that study, individuals rated the odour pleasantness of various foods contained in sealed containers at three timepoints: baseline, after chewing (but not swallowing) one of the foods, finally after consuming the same food to satiety. Results revealed that pleasantness ratings declined after both simply chewing the food and more sharply after eating the food. A follow up experiment further demonstrated the same pattern when instead of chewing the food, it was smelled for the same amount of time. These findings suggest that SSS is not reliant on food entering the gastrointestinal system and indeed can even be found purely in the olfactory domain; this effect has become known as Olfactory Specific Satiety (OSS). More recent work tested the theory in naturalistic conditions (food college restaurant), where all individuals consumed a 4-course meal: appetizer, starter, main meal, dessert that contained the target flavour/odourant (Fernandez, Bensafi, Rouby, & Giboreau, 2013). They found that pleasantness ratings were lower for the dessert for those individuals who received the appetizer infused with the same target flavour. Hence, though all participants were equally satiated (having eaten the same 4-course meal), the dessert was perceived as less pleasant for those who experienced the same flavour with their appetizer and dessert. One interpretation of this finding is that due to the same flavour in both foods, individuals

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associated the dessert with the previously consumed appetizer and on the basis of SSS/OSS perceived it less favourably. That study was important in demonstrating that OSS can be found beyond the more artificial environments of experiments, also how different foods can become associated to each other on the basis of a common flavour. However, as acknowledged by those authors, since individuals rated the 'flavour' of the dessert, one could concede that the design did not permit the testing of the food odour itself. This is important from a theoretical perspective, i.e. can foods become generalized to associated odours and more broadly, it has implications for the role of odours in food consumption. Relevant here, work has shown that smelling a food odour (orthonasal) rather than experiencing the odour of the food in the mouth (retronasal) was a more accurate predictor of subsequent intake (de Wijk, Polet, Engelen, van Doorn, & Prinz, 2004). This suggests that smelling a food prior to consumption has a crucial role in guiding the amount of food we actually consume.

The present study aimed to answer these questions using a novel design that permitted the manipulation of the degree of association between odour and ingested food. Individuals were allocated to one of three experimental conditions which varied in the degree to which the food was associated to the test odour: Control-no food (No association); Chocolate confectionary (Low association); Fruit based confectionary (High association). Participants provided pleasantness ratings for the odour (*isoamyl acetate*) before and following snack consumption. On the basis of previous related work, we would expect pleasantness ratings to decline for the High association condition. An additional aim of the study was to understand whether these effects would be influenced by the individuals' sensitivity (threshold) to that same odour. Although previous work found that SSS was evident in both normosmic and hyposmic/anosmic individuals (Havermans, Hermanns, & Jansen, 2010), the threshold test for that study utilized a non-food odour (butanol) and since that study was directed more at SSS, did not obtain measures of the test food odour. Therefore in the present study, all participants completed a threshold sensitivity test for the same odour. We tentatively predict that individuals less sensitive to the test odour would exhibit weaker OSS effects.

2. Methods

2.1. Participants

Ninety-four students (70 females) from the University of Portsmouth participated in the study and were aged between 19 and 32 years (M = 20.2 years, SD = 2.4 years). The study was described as examining factors that influence our sense of smell and taste. Individuals who had any problems with their sense of smell were advised not to participate; as were those with any respiratory problems (e.g. asthma) or allergies to certain odours/tastants. The study protocol was given ethical approval from the department's ethics committee (British Psychology Society guidelines).

2.2. Design

The study used a mixed design where participants (Table 1) were tested in cluster groups (6–12 participants) where all participants in each cluster completed the same condition. Each cluster group was assigned randomly to one of three conditions that varied in odour association (Control, Low Association, High Association). Participants completed pleasantness ratings of the odour at two Time points: baseline and post test.

Table 1
Mean (SD) participant characteristics dependent on group.

	Group					
	Control (n = 32)		Low association (n = 31)		High association (n = 31)	
	M	SD	M	SD	M	SD
Age	19.9	1.6	21.0	3.7	19.6	0.7
Hours Since Last Meal	3.3	1.3	2.8	1.1	3.4	1.2
Sex (M:F)	7:25		7:24		10:21	

2.3. Materials

2.3.1. Snack food

For the low association snack, participants consumed one chocolate based confectionary (Mars 'Celebrations' assortment, Tesco Portsmouth, appx 50 kcal), and for the high association, they consumed one fruit associated confectionary (Pear drop, Tesco Portsmouth, appx 15 kcal).

2.3.2. Test for Olfactory Specific Satiety

Two 250 ml squeeze bottles (CJK Packaging, UK) were used for this task. Each bottle contained *isoamyl acetate* diluted with propylene glycol at a concentration of 0.06%. The bottles were labelled 'Odour A' and 'Odour B' to avoid any expectancy effects, i.e. participants knowing they were being exposed to the same odour; this was also consistent with previous work (E. T. Rolls & Rolls, 1997). Participants rated the pleasantness of the odour using a Visual Analogue Scale (VAS), with a 100 mm unmarked line labelled "not at all" and "extremely" at either end and the following text above: 'Please place a vertical mark '|' on the line that represents how pleasant you find the odour.'

2.3.3. Olfactory threshold test

The odour used for the threshold test was *isoamyl acetate*, a food associated (smell of banana/pear) odour used frequently in olfactory food related work (Albrecht et al., 2009; Stafford, Tucker, & Gerstner, 2013), which was diluted in propylene glycol. The odourant was prepared using eleven 250 ml squeeze bottles(CJK Packaging, UK), in 16 dilution steps, starting at 0.06% (Step 1) with each successive step diluted by a factor of two, to the lowest (Step 16). All chemicals were supplied by Fisher Scientific (UK). Prior to the start of testing, participants were familiarized with the odour of the strongest concentration, by squeezing the bottle under the participant's nose (~2 cm) and gently waving it between each nostril to ensure optimal inhalation. The experimenter wore cotton gloves (Boots, Portsmouth) to reduce any cross contamination of odours. To test for olfactory threshold, participants were presented with three bottles (2 of which were blanks, containing the dilutant only) at the weakest concentration. Following presentation of the last bottle of the triplet (counterbalanced), participants were asked which bottle contained the odour (1, 2 or 3). If the participant answered correctly (and it was the lowest concentration), they were presented with the same triplet again (in a different order) and the task repeated until they made a mistake, which resulted in the triplet containing the next (higher) concentration step being presented. Participants threshold was established when they had made three consecutive correct responses. The method of threshold testing used was similar to a previous study (Lam, Sung, Abdullah, & van Hasselt, 2006).