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Stimulus specificity but no dishabituation of sensory-specific satiety ☆

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ABSTRACT

Sensory-specific satiety (SSS) refers to the decrease of pleasure derived from a food with its consumption. In the current study it was examined whether SSS for a specific food can be dishabituated. To this end a total of 40 participants (10 males) received bite sized portions of a test food to repeatedly consume. This typically renders SSS for that food. After such established SSS, the participants ate a different test food repeatedly during a period of 10 min or played a computer game (i.e., Tetris), depending on the experimental condition. It was expected that the consumption of another food would induce dishabituation of SSS for the original test food. The participants indeed demonstrated SSS to the test food, but irrespective of condition this SSS proved stable. It is concluded that SSS is stimulus (i.e., food) specific but not subject to dishabituation.

Introduction

Sensory-specific satiety (hereafter SSS) comprises relatively decreased pleasantness derived from a food with the consumption of that food (Hetherington, 1996; Rolls, 1986; Rolls, Rolls, Rowe, & Sweeney, 1981). One mechanism generally thought to underlie SSS is response habituation. Indeed, Epstein, Temple, Roemmich, and Bouton (2009) recently stated that in the context of food consumption the two terms are often used interchangeably (see e.g., Morewedge, Huh, & Vosgerau, 2010; Redden, 2008).

Response habituation comprises a decrease in responsiveness to a particular stimulus with repeated or prolonged stimulation. For example, a loud noise will elicit a startle response but with repeated presentations of the noise this startle response habituates (Thompson, 2009). Habituation is sometimes referred to as single stimulus learning, the learning that a potentially dangerous stimulus is in fact harmless and can be ignored. To conclude that any reduction in behaviour with repeated stimulation is the result of learning requires the refutation of several alternative explanations, such as sensory adaptation and fatigue. One may stop responding to a loud noise if one can no longer hear the noise, and one stops responding to the noise if one is simply too tired to respond. This implies that habituation is stimulus specific and this certainly holds true for SSS (Epstein et al., 2009). In fact, this food specificity is what defines SSS. Without such specificity, there simply is no SSS. SSS is important with regard to meal intake. With the development of SSS for a specific food, less is eaten of a second serving of that food compared to the consumption of another novel food (Rolls et al., 1981). Furthermore, motivated responding for a specific food has been found to decrease with repeated consumption of the food, but this motivated responding recovers when one is given the opportunity to work for a new food (Epstein, Robinson, Roemmich, Marusewski, & Roba, 2010; see also Havermans, Janssen, Giesen, Roefs, & Jansen, 2009).

Another test for habituation concerns demonstrating the immediate recovery of the habituated response to the original stimulus, or dishabituation. If stimulation is changed or continued in a different environmental setting (Marlin & Miller, 1981; Vogel & Wagner, 2005) habituated responding will show at least partial recovery; that is, the change in stimulation serves to restore responding to the original habituating stimulus (Epstein et al., 2009). As a general rule, any response that can be habituated can also be dishabituated (Thompson, 2009). Therefore, if SSS can be ascribed to a habituation process, one would expect that a food change would attenuate SSS, indicative of dishabituation. There are few studies examining such an effect of food change and the results of these studies do not unequivocally demonstrate dishabituated SSS. For example, Wisniewski, Epstein, and Caggiula (1992) found that participants after eating a palatable food until satiation showed relatively stronger salivation, increased consumption and liking for a second serving if that serving was another food. Hetherington, Foster, Newman, Anderson, and Norton (2006) demonstrated in a series of two experiments that the expected decline in pleasantness ratings with the consumption of a test food is attenuated when participants regularly had to taste a different food. Distraction appears to delay sensory satiation (Brunstrom & Mitchell, 2006). These studies suggest it is possible to dishabituate SSS.

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Brondel, Lauraine, Van Wymelbeke, Romer, and Schaal (2009) hypothesized that if one assumes that habituation underlies SSS, increasing the number of alternations between foods in a meal should undermine habituation and hence increase intake. Repeatedly alternating consumption of two different foods affected ad libitum consumption of the test food at test. With a single repetition, food intake was relatively augmented, suggesting that food change indeed undermines SSS. However, in the case of many repeated food alternations, consumption of the test food decreased. It is possible that the single food alternation dishabituated SSS established for the test food, but it is impossible to ascertain whether there was any SSS to dishabituate.

In a recent study, Havermans, Siep, and Jansen (2010) examined whether SSS is less pronounced when at post-test the test food is evaluated after the tasting of other previously unconsumed control food items. If SSS is a form of habituation it should be less pronounced when at post-test one is required to taste the test food after tasting the different control food items. Using this paradigm, Havermans et al. failed to find any indication for dishabituated SSS. However, one might argue that the manipulation employed for that study was too subtle and hence too weak to exhort any notable dishabituation. Perhaps the intermittent consumption of a larger volume of food for a longer period of time would be a more powerful and thus more effective method for dishabituating SSS. For the present study, I therefore examined whether the repeated consumption of a food can abolish previously established SSS to another food.

Methods

Participants

A total of 40 participants (10 males; age range 19–24 years) were recruited among the undergraduate student population of Maastricht University. Participant characteristics are displayed in Table 1. All participants received course credits in return for their participation. The experiment was approved by a local ethical committee.

Procedure and design

Participants were instructed not to eat or drink anything (except water) at least 2 h prior to participation. Participants were tested individually during weekdays between noon and 5 PM. Upon arrival, the participant received both verbal and written information about the experimental procedure and signed a consent form. The participant then indicated how hungry s/he was on a 100-mm line scale that ranged from 0 "not at all hungry" to 100 "very hungry".

Participants were tested individually in a quiet research laboratory. Participants visited the lab twice on separate days for a specific experimental session: A or B. Sessions A and B were separated 2–7 days. In each session the participant would first eat and rate five different foods served in bite sized portions. The foods were fresh tomatoes (~15 g per portion, 4 kcal; Tommies Snoeptomaatjes, Greenco Packing, Honselersdijk, The Netherlands), fresh cucumber (~15 g per portion, 2 kcal), cheese (~7 g per portion, 26 kcal; Goudse kaas, Plus Retail, De Bilt, The Netherlands), cervelat sausage (a cooked and dried sausage; ~7 g per portion, 26 kcal; Limburgse cervelaat – 'mós se preuve', Snijders Vleeswaren, Born, The Netherlands), and crackers (~6 g, 26 kcal; SuperUnie, Beesd, The Netherlands). For this first taste test ('taste test 1') the participant had a rating form with the following questions for each food: 'How much do you like the appearance of the food?', 'How much do you like the smell of the food?', 'How much do you like the taste of the food?', and 'How much would you like to eat the food?'. The questions were answered by scoring on a corresponding 100-mm line scale ranging from 0 'not at all' to 100 'very much'.

Next, irrespective of session, the participant tasted and consumed a test food at four instances. Test food 1 was always served as two bite sized portions and participants had to consume both portions. The experimenter would instruct the participant to first take a portion, to carefully look at it, smell it and to taste it, chew it and finally to swallow it. This 10 min long signalled exposure procedure differs from the more common ad libitum consumption instruction (see e.g., Rolls et al., 1981), but it has been found to induce strong SSS (see e.g., Havermans, Hermanns, & Jansen, 2010; Havermans, Siep, et al., 2010) and it allows for control over the volume consumed, and potential individual differences in bite size and chewing rate. Next, the participant had to taste and to evaluate all five foods again. After this second evaluation ('taste test 2') sessions A and B procedures diverged.

In session A, the second evaluation of the foods was followed by a signalled exposure procedure similar to the procedure before the second evaluation. However, the food ('test food 2') to which one was exposed in this second signalled exposure was different from that of test food 1. This was followed by a third evaluation of all five foods ('taste test 3').

In session B, taste test 2 was followed by a 10 min break during which the participant was not permitted to leave the laboratory but was instructed to play Tetris on the laboratory desktop computer. This break was followed by taste test 3. The order in which the participant received the two sessions A and B was counterbalanced between participants with half of the participants first receiving A and the other half first receiving session B. The allocation of the different foods to serve as test food 1, test food 2, or control food was also balanced between participants. With five foods there are four different possible combinations of a specific test food 1 with another food to serve as test food 2. Given the range of five foods this leaves 20 possible combinations of test foods. These combinations of foods were randomly assigned to the 20 participants who were to receive session A first, and similarly to the 20 remaining participants who first received session B. Note that for each participant the same food served as test food 1 in sessions A and B. The experimental procedure and design is displayed in Table 2.

With completion of both sessions the participant was thanked and received his/her course credits. All participants were fully debriefed on the hypothesis, primary aim and results of the experiment via email when all participants had been tested and data had been processed and analyzed.

Statistics

Separate means were calculated for the ratings for the unconsumed control foods (i.e., the food items that were never consumed in a signalled exposure procedure throughout the experiment) for each taste test (1–3) and for each separate session. As the pleasantness ratings for appearance, smell, and taste, and the ratings for desire to eat at baseline (i.e., taste test 1) correlated very highly (Pearson bivariate correlation coefficients r were all statistically significant and ranged between .34 and .83), these ratings were averaged into a single hedonic rating score for each separate food (i.e., test foods 1 and 2 and the control foods) and for each taste test

Table 1
Sample participant characteristics displaying mean age, mean hunger, and gender distribution.

Total number of participants	40 (10 men; 30 women)
Mean age (in years)	21.23
Mean hunger prior to session A	61.0
Mean hunger prior to session B	61.5

Table 2
Procedure and design of the study.

	Time →				
Session A	Taste test 1	10 min exposure to 'Test food 1'	Taste test 2	10 min exposure to 'Test food 2'	Taste test 3
Session B	Taste test 1	10 min exposure to 'Test food 1'	Taste test 2	10 min playing Tetris	Taste test 3

Note. The taste tests comprised sampling and evaluating 'Test food 1', 'Test food 2', and 'Control foods'.

(1–3). These averaged hedonic ratings served as the dependent variable in a repeated measures ANOVA with Session (2: A versus B), Taste test (3: 1–3), and Food (3: test food 1, test food 2, control foods) as the within-subject factors.

Results

The repeated measures ANOVA rendered a significant effect of Taste test [$F(2,78) = 26.40$, $p < .001$, $\eta^2_{partial} = .40$], and a significant main effect for Food [$F(2,78) = 9.74$, $p < .001$, $\eta^2_{partial} = .20$]. Further, a significant two-way Session × Taste test interaction effect was found [$F(2,78) = 4.27$, $p = .017$, $\eta^2_{partial} = .10$] as well as a Session × Food interaction [$F(2,78) = 3.37$, $p = .039$, $\eta^2_{partial} = .08$] and a Taste test × Food interaction [$F(4,156) = 19.47$, $p < .001$, $\eta^2_{partial} = .33$]. Note that these effects are qualified by an overarching Session × Taste test × Food three-way interaction, $F(4,156) = 9.11$, $p < .001$, $\eta^2_{partial} = .19$. Scrutinizing this three-way interaction, three Session × Taste test ANOVAs for each food (test food 1, test food 2, and control foods) were conducted separately examining the repeated contrasts between taste tests 1 and 2, and between taste tests 2 and 3. Results for these analyses are displayed in Fig. 1, showing the mean hedonic ratings for test food 1 (top panel), test food 2 (middle panel), and the control foods (lower panel) with each taste test (1–3) for each separate session (A: signalled exposure to test food 2 after the second taste test; B: playing Tetris after the second taste test).

For test food 1, a significant effect of Taste test was found when examining the contrast between taste tests 1 and 2, meaning that the hedonic ratings for test food 1 decreased after systematically being exposed to it [$F(1,39) = 32.70$, $p < .001$, $\eta^2_{partial} = .46$], indicative of SSS. In case of dishabituation one would expect this established SSS for test food 1 to substantially recover after systematic exposure to test food 2. In other words, when focussing on the contrast in hedonic ratings from taste test 2 to taste test 3, one would expect to see a Session × Taste test interaction. No such interaction was found though, $F(1,39) = .70$, $p = .41$, $\eta^2_{partial} = .02$. Furthermore, no recovery from taste 2 to taste test 3 irrespective of session was found either, $F(1,39) = .83$, $p = .37$, $\eta^2_{partial} = .02$. In other words, contrary to the central hypothesis the established SSS for test food 1 remained unaffected by subsequent consumption of another food.

For test food 2, one would not expect to see significant changes in hedonic ratings from taste test 1 to taste test 2. Indeed, no such changes were found [$F(1,39) = .01$]. However, one would expect to see a Session × Taste test interaction when examining the contrast in hedonic ratings from taste test 2 to taste 3, that is, one would expect to see a significant decrease in ratings for test food 2 only when having been exposed to this food. This two-way interaction was found, $F(1,39) = 22.19$, $p < .001$, $\eta^2_{partial} = .36$. Subsequent post hoc *t*-tests show that the decrease in hedonic ratings from taste test 2 to taste test 3 is significant for session A, $t(39) = 5.81$, $p < .001$, but not for session B, $t(39) = 1.50$, $p = .14$.

For the control foods, only a significant effect of Taste test was found when contrasting hedonic ratings for taste test 2 with taste test 3, $F(1,39) = 12.41$, $p = .001$, $\eta^2_{partial} = .24$. This finding implies an overall decrease in hedonic ratings for the control food at the end of the experiment, presumably as the result of repeated tastings. In sum, the results of interest indicate that systematic signalled exposure to a given food induces SSS for that food that does not recover rapidly nor dishabituates with extensive exposure to another food.

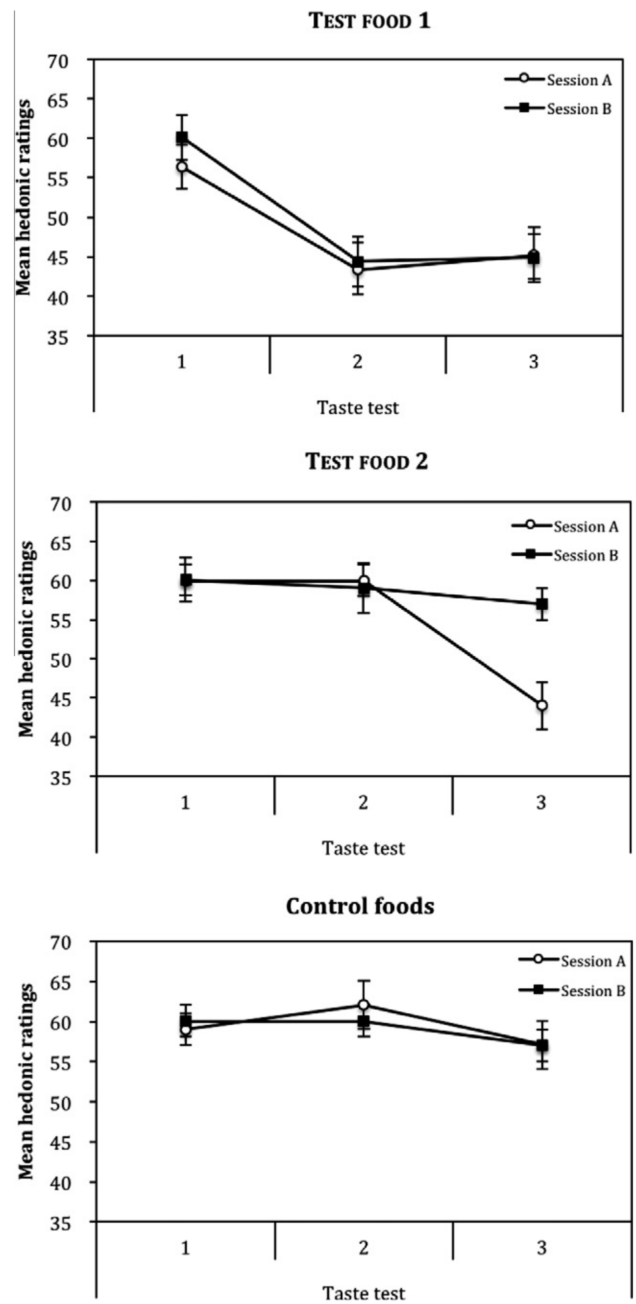

Fig. 1. The mean hedonic ratings (±SEM) for each food (i.e., Test food 1, Test food 2, and Control foods) with each taste test (1–3) separately for sessions A and B.

Discussion

In the present study, it was examined whether the repeated consumption of a food would dishabituate previously established

SSS to another test food. Taken together, the results signify strong SSS for the test foods with consumption, but there appears to be no evidence for the consumption of test food 2 (and the apparent SSS for that food) dishabituating SSS for test food 1 at the third and final evaluation of the foods. In other words, the results show a clear pattern of SSS, but the food change in session A did not dishabituate such SSS.

As discussed earlier, if SSS is the result of a habituation process one would expect that, apart from stimulus specificity, it is sensitive to dishabituation (Epstein et al., 2009; Thompson, 2009). In the present study, the decrease in pleasantness ratings and desire to eat showed stimulus specificity, but SSS appears insensitive to a dishabituation procedure. It should be noted that the absence of dishabituation cannot easily be attributed to general procedural errors. The experimental procedure reliably allowed for the development of strong SSS. Moreover, the present pattern of results is not an isolated finding. In a prior study, Havermans, Hermanns, et al. (2010) also failed to find evidence for dishabituation of SSS. To my knowledge, there are no studies definitively showing dishabituation of SSS. Therefore, it seems that one can delay SSS (see also Brondel et al., 2009; Brunstrom & Mitchell, 2006; Hetherington et al., 2006), but one cannot instantly dishabituate it.

The finding that SSS is stimulus specific but not subject to dishabituation does not imply that SSS is no habituation. Indeed, as was recently argued, stimulus specificity in itself is sufficient to dissociate any response decrement as the result of repeated stimulation (including SSS) from sensory adaptation or fatigue (Rankin et al., 2009). The food specific decrease in liking is associated with neuronal habituation in the orbitofrontal cortex (OFC; Rolls, 2005). For example, in an fMRI study by O'Doherty et al. (2000) participants showed decreased activation in the OFC when exposed to an odour of a food they had just eaten to satiety, but no such decrease to another food odour (see also Rolls, Critchley, Browning, Hernadi, & Lenard, 1999).

Interestingly, altered valuation of a food stimulus due to prior experiences with that food may be an even simpler adaptive mechanism than is the single stimulus learning implicated in typical response habituation. Higgs, Williamson, Rotshtein, and Humphreys (2008) had two amnesic patients eat a meal of sandwiches until satiety. The patients showed a decrease in liking for these sandwiches relative to unsampled foods, indicating SSS. The patients' SSS did not differ from SSS observed in control participants. However, compared to the control participants, the amnesic patients tended to eat more of the sandwiches. One could argue that the patients showed impaired habituation of motivated responding (i.e., consummatory behaviour; see also McSweeney & Murphy, 2009) despite intact SSS.

In sum, the present study results are in line with previous findings (i.e., Havermans, Siep, et al., 2010) that together suggest that established SSS is stimulus specific but not subject to dishabituation. Note that this result does not imply or warrant the conclusion that SSS is not some form of response habituation. Although dishabituation is nearly as ubiquitous as habituation itself, SSS may simply be viewed as an exception to the 'rule' that "all responses of mammals that can be habituated can also be dishabituated" (Thompson & Spencer, 1966, p. 19). To what degree SSS can still be understood in terms of response habituation or some other form of stimulus specific adaptation requires further research.

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