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Sensory-Specific Satiation With a Pinched Nose and Eyes Closed: Testing the Sensory Modality Specificity of Satiation

Remco C. Havermans and Anna-Theresa Mallach

Clinical Psychological Science, Faculty of Psychology and Neuroscience, Maastricht University, PO Box 616, 6200 MD Maastricht, the Netherlands

Correspondence to be sent to: Remco C. Havermans, Clinical Psychological Science, Faculty of Psychology and Neuroscience, Maastricht University, PO Box 616, 6200 MD Maastricht, the Netherlands. e-mail: r.havermans@maastrichtuniversity.nl

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Abstract

Sensory-specific satiation refers to the decrease in pleasantness derived from a consumed food relative to other unconsumed foods. In the current study, it was investigated to what extent sensory-specific satiation is modality specific. To this end, 80 female participants ate a preferred snack until full while wearing (or not wearing) a blindfold and/or a nose clip. Impaired vision should impede satiation for the appearance of the consumed test snack. Obstructing olfaction should undermine satiation for the smell of the test snack. Indeed, when vision was obstructed, hedonic ratings of specifically snack appearance did not decrease as much. When olfaction was blocked, the hedonic ratings for the flavor of the test snack did not show as much of a reduction. It is concluded that, to a degree, sensory-specific satiation is indeed modality specific.

Key words: olfaction, sensory-specific satiation, vision

Introduction

Sensory-specific satiety comprises a decrease in liking and motivation for a food with its consumption, relative to other unconsumed foods (Rolls et al. 1981; Hetherington 1996). Sensory-specific satiety occurs within a meal. It recovers spontaneously, slowly, in the absence of further orosensory exposure to the food (Hetherington et al. 1989; Weenen et al. 2005; Havermans et al. 2012). It is clear that sensory-specific satiety plays an important role in eating behavior as it motivates food variety seeking (Rolls et al. 1981) and limits the likelihood of overeating a particular food within a meal (Hetherington 1996). Sensory-specific satiety is thus an important determinant of both food selection and intake.

One might argue that the term "sensory-specific satiety" does not accurately describe the actual effect. Because it contributes to meal termination and hence is a process that already takes place during consumption (rather than being a postingestive effect), sensory-specific satiety is more accurately described as satiation. This sensory-specific *satiation* then is deemed specific in the sense that the satiation seems to depend solely on sensory input (Rolls et al. 1981). Further, the phenomenon is food specific in that the decrease in liking for a consumed food only generalizes to other foods that share sensory characteristics with the consumed food (Rolls et al. 1988; Guinard and Brun 1998; Havermans et al. 2009; Griffioen-Roose et al. 2010).

Sensory-specific satiation is the "changing hedonic response to the sensory properties of a particular food as it is consumed" (Rolls 1986, p. 95). All sensory aspects of the particular food being consumed (e.g., its appearance, smell, taste, and mouth feel) typically become less liked. This is perhaps not very surprising as eating is an orosensory experience that involves a multisensory percept, an amalgam of different sensory inputs commonly referred to as flavor (Auvray and Spence 2008). A food's appearance, the sound a food makes when chewing it, its taste, its texture and mouth feel, and its aroma all contribute to flavor and the enjoyment of a food. People, however, are generally able to recognize and decompose the individual sensory characteristics contributing to the experienced flavor (Stevenson 2012). This is important as it allows for the possibility that sensory-specific satiation is modality specific. Does one experience a greater decrease in pleasantness for an eaten food if there is a match between the sensory modality (e.g., smell) in which it was experienced and the particular modality in which its pleasantness is assessed? And is there no or much less sensory-specific satiation in the absence of such a sensory modality match?

In the present study, it was hypothesized that sensory-specific satiation is modality specific. To test this hypothesis, participants were instructed to eat a certain snack food until pleasantly full. The participants wore a blindfold (or not) and a nose clip (or not), depending on the condition to which they were assigned. Specifically, we hypothesized that obstructed vision would save the appearance ratings (but not smell or overall flavor ratings) of the test snack from satiation. Further, obstructing olfaction would particularly save hedonic smell ratings from satiation.

Materials and methods

Participants

A total of 80 participants (all female) were randomly assigned to 1 of 4 groups of equal size. Considering that men tend to eat more than women do and that there are usually far more women signing up for participation in our experiments, we chose to only include women in the present study. Participants were recruited among the student population of the Maastricht University Randwijck Faculties (i.e., the Faculty of Health, Medicine and Life Sciences and the Faculty of Psychology and Neuroscience). Candidate participants did not have an olfactory deficit and they had to have normal (or corrected to normal) vision. As outlined in Table 1, mean age of the participants in the 4 groups did not significantly differ.

The Ethical Committee Psychology approved the study. The committee evaluates all research initiatives of all the research staff members of the Faculty of Psychology and Neuroscience at Maastricht University. Upon approval, the responsible investigators commit themselves to treat the participants in line with the ethical principles regarding human experimentation as stated in the Declaration of Helsinki. The responsible investigators also guarantee that the participants are free to withdraw or halt further participation if they wish to do so. Furthermore, the researchers commit themselves to optimizing the quality and rigor of the research including the statistical analyses and the communication of the results.

Procedure and materials

All participants were instructed not to eat and drink anything for 2h prior to their participation. On arrival, participants first received written information on the further experimental procedure (though not on the research aims and question) and signed a consent form if they still wished to participate. Participants were tested on weekdays between 10 AM and noon either individually or in a small group (n = 2–5) in a large laboratory room containing multiple separate testing compartments.

The participant was seated at a table in one of the compartments. Next, she rated her momentary hunger on a 100-mm line scale ranging from 0 “not at all hungry” to 100 “extremely hungry.” Then, she would receive small portions of 3 snack foods to taste and evaluate: salted sticks (8 g; 1527 kJ/100 g; Albert Heijn), biscuits with a milk chocolate layer (28 g; 2121 kJ/100 g; Albert Heijn), and small bite-sized crackers (16 g; natural flavor, 1807 kJ/100 g; LU/Kraft Foods). Participants were not obliged to eat all of each portion. The snacks were served all at once and the participant decided for herself in which order she wished to taste and evaluate the different snacks. The participant would rate her momentary liking for the food’s appearance, smell, and flavor on separate 100-mm line scales ranging from 0 (highly disliked) to 100 (highly liked). With regard to the hedonic flavor ratings, we explained to the participants beforehand what we mean by flavor (i.e., not just taste but also aroma and mouthfeel of the food).

Next, the participant received a nose clip (BECO Beermann) and a blindfold (TravelSafe) to wear (or not)

Table 1 General participant characteristics for each separate condition

	Condition				
	Eyes and nose	No eyes but nose	Eyes but no nose	No eyes and no nose	
N	20	20	20	20	
Mean (+SD) age in years	20.9 (2.0)	20.6 (3.4)	20.7 (1.7)	21.4 (4.1)	ns
Mean (+SD) hunger	56 (21)	51 (22)	57 (22)	52 (26)	ns
Mean (+SD) DEBQ—emotional eating	3.3 (0.7)	3.3 (0.7)	3.2 (0.9)	3.4 (0.7)	ns
Mean (+SD) DEBQ—external eating	2.6 (0.5)	2.6 (0.5)	2.3 (0.2)	2.8 (0.4)	$F_{3,74}$ = 5.69, P < 0.01
Mean (+SD) DEBQ—restrained eating	3.2 (0.9)	2.7 (0.8)	2.9 (0.7)	2.6 (0.6)	ns

SD, standard deviation. DEBQ refers to Dutch Eating Behavior Questionnaire. The mean item scores for each separate subscale of the DEBQ are provided. Note that 2 participants (from condition “eyes and nose”) did not complete the DEBQ. When appropriate, the potential difference between the groups was analyzed for each separate participant characteristic. The results of these analyses are displayed in the last column. Only the P values of significant F-tests are reported (P < 0.05); in the other cases, the test result is simply referred to as nonsignificant (ns).

according to the condition she was assigned to. The participant was then asked to pick her favorite snack of the 3 just tasted at the premeasurement. This food was then served as the test snack. The participant was instructed to eat as much of the test snack until pleasantly full. The experimenter monitored adherence to the instructions and determined the amount of eaten food with a balance capable of weighing to the nearest gram.

The ad libitum consumption of the test snack was followed by a postmeasurement in which the participant was again instructed to taste and evaluate the 3 snack foods in the same manner as at the premeasurement. Note that at both pre- and postmeasurement, none of the participants had to wear a nose clip and/or blindfold. Further, the participants filled out the Dutch Eating Behavior Questionnaire (DEBQ; van Strien et al. 1986). This questionnaire assesses one's penchant for disinhibited eating in response to either external cues ("external eating") or negative emotional cues ("emotional eating"), and it measures one's degree of dietary restraint ("restrained eating"). Variations in dietary restraint and the tendency to disinhibit are thought to contribute to food intake. Therefore, when considering food intake, the DEBQ questionnaire scores allow us to control for individual differences in external eating, emotional eating, and restraint.

The whole experimental procedure took approximately 30 min to complete upon which the participant was thanked and received a €750 monetary voucher for remuneration.

Data reduction and analyses

The present experimental design is a 2 × 2 factorial design, rendering a total of 4 conditions: no nose/no eyes; no nose/eyes; nose/no eyes; nose/eyes. To test for the effects of vision (eyes vs. no eyes) and olfaction (nose vs. no nose) on the consumption of one's preferred test snack, a Vision × Olfaction analysis of covariance (ANCOVA) was conducted. As level of external eating differed significantly between the 4 conditions (see Table 1), the average external eating DEBQ item score was added as a covariate. To account for idiosyncratic differences in selected test snack, we calculated the amount of energy (in kilojoules) consumed to serve as the dependent variable.

To test for a food specific shift in hedonic ratings for the flavor, smell, and appearance of the snack foods and whether such an effect depends on being able to see and/or smell the food, we first calculated the difference between these hedonic ratings. We subtracted the postconsumption ratings from the preconsumption ratings for the consumed test snack and the 2 unconsumed test snacks. Note that the difference scores for the 2 unconsumed foods were averaged into a single difference score. The difference scores (i.e., for the consumed and for the unconsumed snack foods) then served as dependent variable in 3 Snack (consumed test snack vs. unconsumed test snacks) × Vision × Olfaction analyses of variance (ANOVAs) for each evaluated sensory aspect (i.e., flavor, smell, appearance).

Results

Energy consumption

First, we tested whether vision (obstructed/unobstructed) and olfaction (impaired/unimpaired) had any effect on consumption of the snacks. Figure 1 displays the mean energy consumed in all 4 conditions.

The ANCOVA revealed a significant effect of Olfaction, $F_{1,73} = 15.40$, $P < 0.001$, $\eta^2_{\text{partial}} = 0.17$, indicating that participants ate less when they could not smell their test snack. No effect of Vision was found, $P = 0.198$, but there was a significant Vision × Olfaction interaction, $F_{1,73} = 5.67$, $P = 0.02$, $\eta^2_{\text{partial}} = 0.07$. The covariate was not significant, $P = 0.913$, indicating that variation in self-reported external eating did not predict the extent of ad libitum consumption of the test snack.

To further examine the Vision × Olfaction interaction, we conducted 2 ANOVAs testing for a potential effect of Vision when being able to smell the food and when being unable to smell the food. These ANOVAs revealed that when participants could smell the food, they ate more if they could not see the food than if they could see the food ($F_{1,38} = 5.42$, $P = 0.025$). However, when they could not smell the food, the effect of vision disappeared ($F_{1,38} = 0.66$, $P = 0.423$).

Hedonic ratings

Sensory-specific satiation was determined for each separate hedonic rating (i.e., hedonic appearance, smell, or flavor ratings) in a 3-way Snack × Vision × Olfaction ANOVA.

Figure 2 depicts the mean shift in appearance liking from premeasurement to postmeasurement (+standard error of the mean [SEM]) for each condition. With regard to the appearance ratings, it was found that the appearance liking

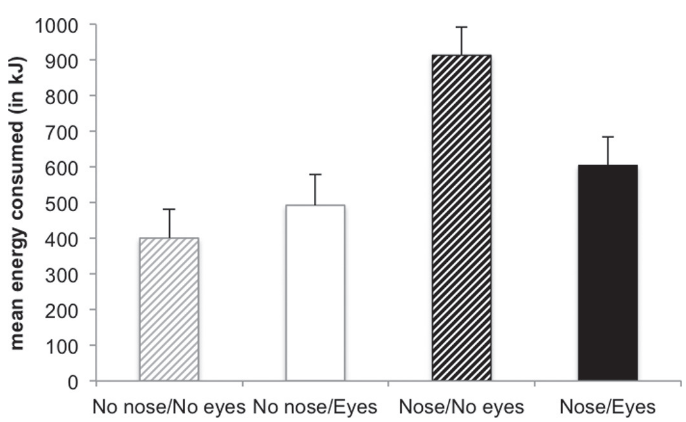

Figure 1 Mean energy consumption (+SEM) of the test snack (in kilojoules) for each separate condition.

of the test snack significantly decreased from premeasurement to postmeasurement relative to the unconsumed snacks ($F_{1,76}$ = 49.38, P < 0.001, η^2_{partial} = 0.39) and that this Snack effect appeared to be qualified by a near significant 2-way Snack × Vision interaction, $F_{1,76}$ = 3.08, P = 0.08, η^2_{partial} = 0.04. The pattern of means suggests that the participants who could see what they were eating tended to show stronger sensory-specific satiation for the test snack in terms of appearance ratings. No other main effects (i.e., for Olfaction and Vision) were found (largest $F_{1,76}$ = 1.25). And no further interaction effects (Snack × Olfaction; Olfaction × Vision; Snack × Olfaction × Vision) were found (all Fs < 1).

Figure 3 displays the mean shift in smell liking (+SEM) from premeasurement to postmeasurement for all 4 conditions. When considering the smell liking ratings, a significant main effect of Snack was found ($F_{1,76}$ = 15.47, P < 0.001, η^2_{partial} = 0.17), qualified by a significant Snack × Vision × Olfaction 3-way interaction effect, $F_{1,76}$ = 5.39, P = 0.02, η^2_{partial} = 0.07, signifying that sensory-specific satiation was strongest when one could both see and smell the test snack during its ad libitum consumption. No other main effects (i.e., for Olfaction and Vision) were found (largest $F_{1,76}$ = 2.50 for factor Vision, P = 0.12, η^2_{partial} = 0.03). And no further interaction effects (i.e., Snack × Olfaction; Olfaction × Vision; Snack × Vision) were found (largest $F_{1,76}$ = 1.14).

Regarding the hedonic flavor ratings, sensory-specific satiation was again reflected by a significant main effect of Snack, $F_{1,76}$ = 59.30, P < 0.001, η^2_{partial} = 0.44. This main effect was qualified by an overarching 2-way Snack × Olfaction interaction ($F_{1,76}$ = 4.08, P = 0.05, η^2_{partial} = 0.05) indicating stronger sensory-specific satiation when one is able to smell the snack. No other main effects (i.e., for Olfaction and for Vision) were found, largest $F_{1,76}$ = 2.20 for the factor Vision,

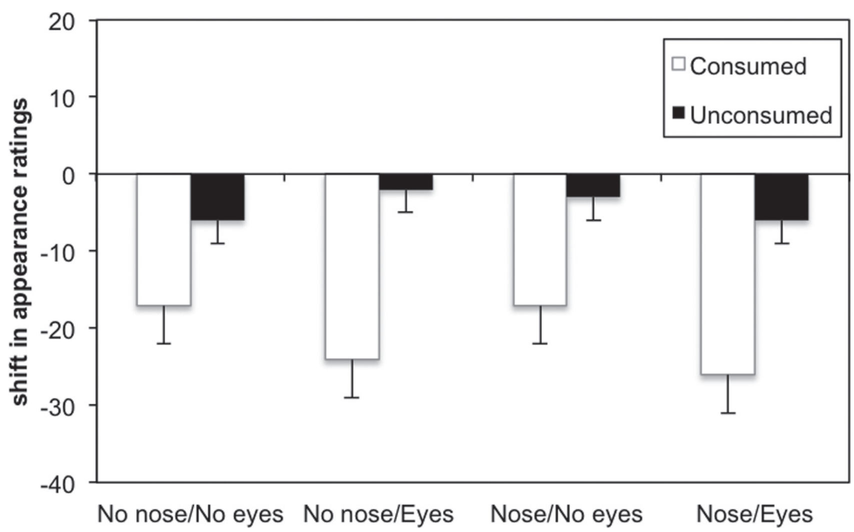

Figure 2 Mean shift in hedonic appearance ratings for each condition (+SEM).

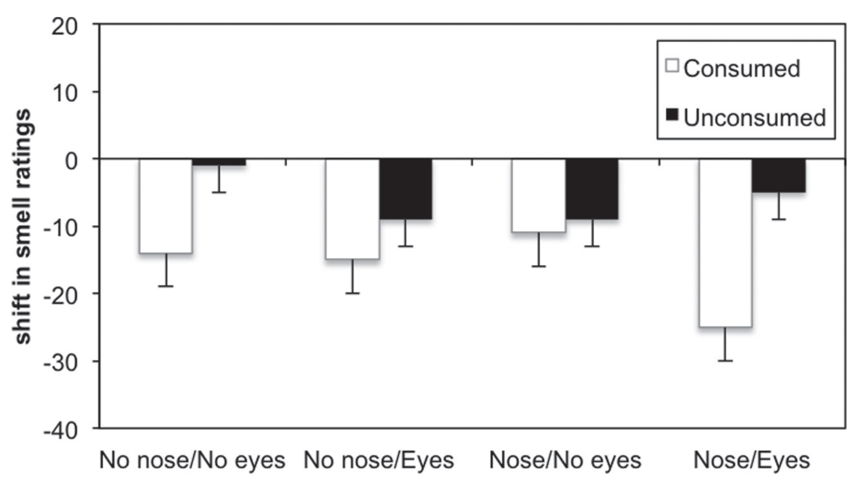

Figure 3 Mean shift in hedonic smell ratings for each condition (+SEM).

$P = 0.14$, $\eta^2_{partial} = 0.03$. Further, no interaction effects (i.e., Snack × Vision; Olfaction × Vision; Snack × Olfaction × Vision) were found (largest $F_{1,76} = 1.33$). The mean shift in hedonic flavor ratings for the consumed test snack and the unconsumed snacks for each separate condition is displayed in Figure 4.

Discussion and conclusion

In the present study, we examined whether sensory-specific satiation is modality specific. We tested whether especially the evaluation of a consumed food's appearance is less subject to satiation when one could not see the food with its consumption. Further, it was tested whether particularly the evaluation of a food's smell is less subject to satiation if one could not smell the food one had to eat until pleasantly full. The results partly corroborate our hypotheses; that is, participants who could not see their test snack food during consumption seemed to show a smaller decrease in liking for the appearance of the snack food. But note that this effect (as far as one is allowed to call it that) was not statistically significant. Further, hedonic flavor ratings were less affected by consumption when one could not smell the food. When regarding the smell ratings, stronger sensory-specific satiation was observed if participants could both smell and see the test snack during consumption. This makes sense and suggests that obstruction of any sensory modality may disrupt the development of sensory-specific satiation, at least when considering the evaluation of a food smell. Note that this finding is different from what we hypothesized but may be explained in terms of appearance of a food eliciting specific expectations on smell of the food. Seeing a food activates its representation in memory (e.g., Siep et al. 2009). In as much as this representation includes smell, perhaps this is sufficient to induce satiation for its smell. This provides a viable explanation, but it raises the question why this does not seem to extend to flavor evaluation. A possible answer is that smelling a food is contiguous with seeing the food, whereas retronasal olfaction coincides with the taste of a food and its mouth feel. This suggests important differences between the orthonasal and retronasal olfactory perception of a food (see also Stevenson 2012). More research is needed. For example, it would be interesting to test for a potential difference of retronasal versus orthonasal food exposure on the development of sensory-specific satiation for its flavor.

In the current study, participants ate significantly less of a favored snack when their sense of smell was impaired by means of a nose clip. Does this mean that the inability to smell makes one satiate much quicker to a given food (Yeomans 2006)? That seems unlikely. In a recent study among anosmic/hyposmic persons (people with an olfactory deficit), we found no evidence to suggest that a reduced sense of smell affects sensory-specific satiation (Havermans et al. 2010). Anosmia, however, is associated with a decreased quality of life, especially when considering tasting and eating (Toller 1999; Smeets et al. 2009). Food preferences tend to change with olfactory impairment (Aschenbrenner et al. 2008). Some foods just do not taste as good when not being able to smell. A more straightforward and hence parsimonious explanation for the current finding is that the snack foods were less palatable with acute olfactory impairment.

We also found that vision affects ad libitum consumption; that is, one eats more of a given food when one cannot see the food (see also Scheibehenne et al. 2010), though this effect was only apparent when the participants were able to smell the food. Vision did not affect consumption when smell was impaired. Again, this interaction can be explained by arguing that not being able to smell a food makes consuming the food less enjoyable. Regardless of whether one is able to see or not see the food does nothing to change the dullness of an odorless eating experience. Conversely, if one is able to smell a palatable food and enjoy its flavor, not being able to see makes one amenable to losing track of how much one has already eaten.

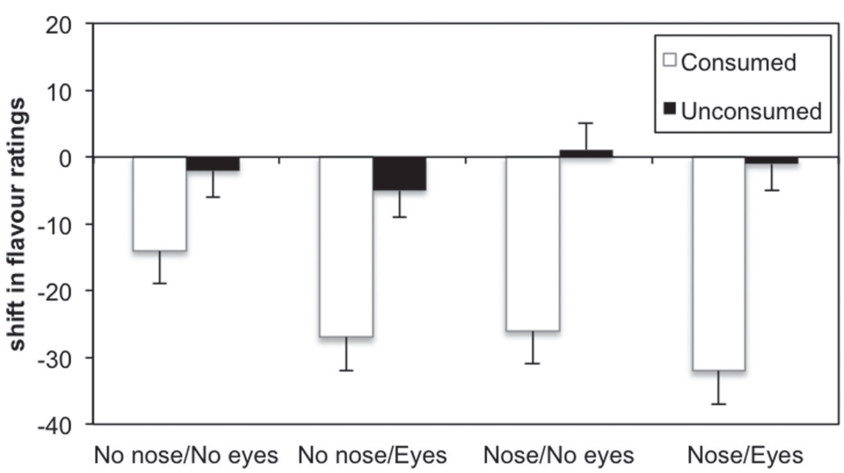

Figure 4 Mean shift in hedonic flavor ratings for each condition (+SEM).

To recapitulate, the present study shows that sensory-specific satiation is modality specific to a degree. Impairing a particular sensory modality during the consumption of a test snack may weaken the otherwise observed decrease in hedonic evaluation of that particular sensory snack characteristic.

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