



Research report

Food intake in response to food-cue exposure. Examining the influence of duration of the cue exposure and trait impulsivity[☆]

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ABSTRACT

The present study experimentally tested whether the effect of olfactory food-cue exposure on young women's food intake was moderated by the duration of the cue exposure and trait impulsivity. The study employed a 2 (food-cue exposure: smell of baked cookies present vs. no-smell present) by 2 (duration of cue exposure: short-term vs. long-term) between-participants design. Participants were 109 normal-weight young women (mean age = 21.6 years) whose food intake was examined during a bogus taste-test. Additional saliva measures were taken during food-cue exposure. Results showed that the duration of the cue exposure did not affect intake. Impulsivity moderated intake, but not saliva flow. Low impulsive females consumed more food when confronted with an olfactory food-cue, whereas high-impulsive females did not eat more after food-cue exposure. Our findings may be explained by the fact that we did not instruct our participants to pay attention to the olfactory food-cue. Results indicate that even people who are normally well controlled are susceptible to the effects of less explicit olfactory food-cues.

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Introduction

Obesity has rapidly increased in prevalence and is becoming a worldwide health problem because of the critical role it plays in diabetes, cardiovascular diseases, and cancer (Hu, 2003). Considering that obesity rates have risen dramatically in a relatively short time frame, genetic factors are not believed to play a predominant role in the current obesity epidemic; rather, the growing consensus among experts is that the environment is driving the current obesity epidemic (Brownell, Schwartz, Puhl, Henderson, & Harris, 2009). This environment includes exposure to copious cues for highly palatable and calorically dense foods (e.g., Blundell et al., 2005). Research has shown that exposure to the sensory properties of food, such as the sight or smell of palatable food, may increase hunger, desire to eat, and actual food intake (e.g., Cornell, Rodin, & Weingarten, 1989; Fedoroff, Polivy, & Herman, 1997; Nederkoorn, Smulders, & Jansen, 2000).

As obesity rates continue to rise, it is important to gain insights into why and under what conditions people are affected by these sensory food cues. Early learning-based models propose that sensory cues elicit craving and cephalic phase responses, which may explain increased intake (Weingarten, 1985; Woods, 1991). How-

ever, after prolonged confrontation with food cues, people habituate to these cues, showing decreases in salivary responses and approach tendencies, which might have the potential to reduce subsequent consumption (Epstein, Temple, Roemmich, & Bouton, 2009). Thus, theoretically, the duration of food-cue exposure may be an important contextual factor influencing food intake.

The majority of studies in which the influence of prolonged (i.e., 5–10 min) sensory food-cue exposure on food intake was directly assessed did not find significant effects among unrestrained eaters (Coelho, Jansen, Roefs, & Nederkoorn, 2009; Coelho, Polivy, Herman, & Pliner, 2009; Fedoroff, Polivy, & Herman, 2003; Fedoroff et al., 1997; Jansen & van den Hout, 1991; Nederkoorn & Jansen, 2002). However, two studies found significant effects, showing that normal weight children (Jansen et al., 2003) and unrestrained young females (Rogers & Hill, 1989) ate significantly less after prolonged exposure to the smell and/or sight of palatable food (Jansen et al., 2003; Rogers & Hill, 1989). In contrast, the few studies that provided people with food cues for a shorter amount of time (i.e., 1–3 min) found increased consumption (Cornell et al., 1989) or increases in the amount of food that unrestrained people actively planned to eat (Ferriday & Brunstrom, 2008). These seemingly contrasting findings support the idea that the effect of sensory cues might be dependent upon the duration of food-cue exposure. To the best of our knowledge, not a single study has manipulated the duration of the cue-exposure to examine whether this assumption holds.

In addition to this contextual factor, dispositional factors may also influence the overall impact of sensory food cues on food intake. To date, research has demonstrated that sensory cues have

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a more powerful effect on obese and/or restrained eating individuals (Herman & Polivy, 2008). Jansen (1998) extended the early learning-based models to explain why restrained people in particular would be more susceptible to sensory food cues. She proposed that food-related cues act as conditioned stimuli, which in turn elicit “cue-reactivity” (a conditioned response), with this conditioning being especially strong in restrained eaters because they tend to experience initial food deprivation and then eat large amounts (unconditioned stimuli) in reaction to a limited amount of food cues (conditioned stimuli). Schachter (1968) used his “internal–external” theory of eating to explain why obese people were more susceptible to (sensory) food cues. He proposed that overeating among the obese resulted from a heightened responsiveness to external stimuli and a decreased responsiveness to internal stimuli. This theory does not focus on why obese people would be more susceptible to food cues, but assumes that obese people are more susceptible to external cues because they do not eat in response to internal stimuli.

It is possible that obese people are more susceptible to food cues because they are more impulsive than lean individuals, as has been consistently found in previous research (Braet, Claus, Verbeke, & Van Vlierberghe, 2007; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006; Rydén et al., 2003). Some research has shown that priming lack-of-control thoughts led to increased food intake among normal-weight women (Guerrieri, Nederkoorn, Schrooten, Martijn, & Jansen, 2009; Rotenberg et al., 2005). In particular, food cues might theoretically elicit eating in impulsive people who tend to respond with insufficient thinking, planning, or control (Solanto et al., 2001), as they may be less able to suppress or block their physiological reactions and craving urges in response to food cues. Thus, eating cues may elicit automatic associative learning reactions—as proposed by early learning-based models—and the amount of impulsivity determines to what extent these automatic reactions are being controlled. Such conclusions are in line with dual-process models, according to which humans’ (eating) behavior is the combined result of automatic, associative, learning (automatic system), and a more reflective system determining whether automatic impulses are being controlled (control system) (Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Strack, Werth, & Deutsch, 2006).

To the best of our knowledge, only a few studies have examined the interactive effect of impulsivity and the food environment on food intake (Guerrieri, Nederkoorn, & Jansen, 2007; Guerrieri, Nederkoorn, & Jansen, 2008; Jansen et al., 2009). Two of these studies manipulated the variety of the food environment (i.e., varied vs. monotonous food offered in a taste test) and did not find evidence for an interaction between the varied food environment and self-reported impulsivity or deficient response inhibition on food intake (Guerrieri, Nederkoorn, & Jansen, 2007; Guerrieri et al., 2008). Thus far, only one study has manipulated the presence of a sensory (olfactory) food cue without finding evidence for an interaction between this food cue and deficient response inhibition to food intake. However, highly restrained females with deficient response inhibition ate more after confronting the sensory food cue (Jansen et al., 2009). To date, the role of self-reported (trait) impulsivity in interactions with sensory food cues remains to be examined, which is particularly relevant considering that, in normal weight populations, the controlling aspect of self-reported impulsivity has been consistently linked to increased food intake while less consistent evidence has been found related to the link between deficient response inhibition and food intake (Guerrieri, Nederkoorn, & Jansen, 2007; Guerrieri et al., 2007).

The main purpose of the current investigation was to address previous gaps in the literature by examining whether and how a theoretically relevant contextual factor (duration of the cue

exposure) and a dispositional factor (trait impulsivity) might moderate the impact of sensory food-cue exposure (i.e., the smell of food) on normal-weight young women’s food intake. As in most previous studies that examined the interaction between impulsivity and the food environment, we focused on females. We hypothesized that normal-weight women would eat more when confronted with a short-lived food cue, whereas they would eat less (or at least not more) when confronted with a food cue of longer duration. We further hypothesized that highly impulsive women would eat more in response to the food cue than low-impulsive women. Theoretically, the conditioned responses in confrontation with sensory eating cues may be larger for restrained eaters; this conditioned response may in particular elicit eating if restrained eating is combined with high impulsivity. Therefore, we measured two- and three-way interactions among the eating cue, impulsivity, and dietary restraint, in correspondence with Jansen’s study. Finally, we examined the impact of food-cue exposure—and the potential interactions with impulsivity and restrained eating—on saliva secretion (as an index of underlying cue reactivity and habituation; we thus expected a similar direction of effects as for food intake).

Methods

Design

The study employed a 2 (food-cue exposure: smell of baked cookies present vs. no-smell present) by 2 (duration of cue: short-term vs. long-term) between-subjects design. Self-reported impulsivity scores were not manipulated and were regarded as continuous variables. Participants were randomly assigned to the different conditions. In the short-term duration condition, participants were exposed to the smell of baked cookies for one minute and had one salivation trial. In the long-term duration condition, participants were exposed to the smell of baked cookies for 15 min and had eight 1-minute salivation trials; between the saliva trials there were 1-minute intervals.

We did not instruct our participants to pay explicit attention to the olfactory food-cue. This was done to enhance ecological validity, as in our “toxic” environment young people are continuously confronted with sensory food-cues to which no specific attention is paid (e.g., the smell of high-caloric food in shops or at railway stations).

Participants

A total of 158 female students volunteered for this study. All participants were recruited through an Internet sign-up program of the Behavioural Science Institute of the Radboud University Nijmegen and were included only if they had a body mass index (BMI; calculated as kg/m^2) within the normal-weight range ($18 < \text{BMI} < 25$). We excluded 19 overweight participants ($\text{BMI} > 25$) from our study. Additionally, 17 females were excluded from further analyses because they became aware of the actual aim of the study (i.e., cue-exposed food intake). Moreover, 11 females were excluded because they reported problems with smelling and two females had invalid or incomplete records. The final sample, then, consisted of 109 female students with a mean age of 20.94 years ($SD = 2.14$) and a mean BMI of 21.61 ($SD = 1.66$). Participants were awarded course credit (for educational requirements) or a 10-euro gift cheque for completing the study. The Ethics Committee of the Faculty of Social Sciences of the Radboud University Nijmegen approved the study protocol and all participants provided written informed consent.

Procedure

At scheduling, participants were asked to refrain from eating, drinking, or smoking at least 3 h prior to the experiment. Asking

participants to refrain from eating for a certain period of time before the experiment facilitates controlling for individual variations in hunger (Polivy, Heatherton, & Herman, 1988). Under the pretext of a study on the influence of biological and psychological factors on food preferences, participants were asked to rate the taste of three different kinds of flavored cookies (cardamom, ginger, and cinnamon). This was a cover story to prevent participants becoming aware of the actual aim of the study. Participants were told that they had to taste different kinds of cookies at the end of the experiment to prevent them from preparing for food intake during the food-cue exposure.

The experiment took place in an interaction room at the BSI lab of the Radboud University Nijmegen. The interaction room was about 10 m², with white walls and a table with tablecloth and a chair placed at one side, and a comfortable chair placed at the other side. Participants were invited between 11 a.m. and 4 p.m., during the months of February–April, 2010. All sessions took approx. 30–45 min in total.

A research assistant met the participant at the front office of the lab facilities. After providing consent, the participants were accompanied to the laboratory where the procedure of the study was explained. First, they were told that they would spend some time to complete saliva measurements and had to fill out different questionnaires after the salivation trials. Participants were instructed to relax and to sit down in a comfortable chair while they performed the salivation trials. In the ‘smell present’ condition, cookies were baked in an oven in the testing room. In the ‘smell absent’ condition, cookies were baked in another room to prevent any odour of cookies.

After the last salivation trial, the experimenter entered the room again. On the pretext that something had gone wrong with copying the questionnaires, participants were told that the order of the experiment had been changed. They were now instructed to complete the taste-test first. The experimenter provided all participants with a glass of water and three pre-weighed bowls of the different flavored cookies. Each bowl contained 10 little cookies. Participants were asked to taste the cookies and rate the three flavors. It was stressed that participants could eat as much as they liked or needed in order to complete the taste-test. After exactly 10 min, the experimenter returned.

Finally, participants completed a series of questions on impulsivity and general eating behavior. Participants were also asked to write down what they thought the main purpose of the study was, in order to probe for suspicions about the true purpose of the experiment. Finally, the experimenter measured participants’ height and weight in order to calculate BMI.

Measurements

Salivation

Whole mouth parotid salivation was measured using the absorption of saliva by rolls of cotton (Peck, 1959). The participant was seated in a comfortable chair and instructed on cotton roll placement (cylindrical, 8 mm diameter, 37 mm length, Henry Schein Inc., Melville, USA). Per trial, 3 cotton rolls were placed: one on both sides of the mouth and one underneath the tongue. While cotton rolls were in the mouth, the participant was instructed not to talk, to swallow, or to chew on the cotton rolls. For practice, the experimenter (as an example) and participant both put on 3 cotton rolls in their mouth outside the laboratory test room (to avoid exposure to the smell of cookies in the smell conditions). At the end of each trial, participants placed the cotton rolls in plastic bags that could be sealed. The amount of salivation was calculated by taking the pre- and post weight of the cotton rolls. Cotton rolls were weighed to 0.001 g on a precision standard scale (Mettler Toledo AB135s). The primary saliva outcome measure was calculated as the change between baseline and each trial.

Food intake

The cookies were baked using dough from packages of ‘Homemade Complete Mix for American Cookies’ (Homemade BV, Roden, the Netherlands). The cookies had a mean weight of approx. 4 g per cookie and contained a mean of 4.44 kcal per gram. The content of the three bowls of cookies were weighed to the nearest 0.1 g (Kern440) immediately before and after the sessions in order to determine the amount of food (in grams) consumed. We converted the total gram of cookies consumed to the total amount of energy consumed (in kcal).

Height and weight

The research assistant measured each participant’s height and weight following standard procedures (Lohman, Roche, & Martorell, 1998). Height was measured to the nearest 0.5 cm using a stadiometer (Seca 206, Seca GmbH & co., Hamburg, Germany) and weight was measured to the nearest 0.1 kg using a digital scale (Seca Bella 840, Seca GmbH & co., Hamburg, Germany). BMI was calculated as weight in kilograms divided by the square of height in meters

Impulsivity

Impulsivity was measured by the Barrat Impulsiveness Scale (BIS; Patton, Stanford, & Barratt, 1995). This scale consists of 30 items on a 4-point scale, with responses ranging from 1 ‘Rarely/Never’ to 4 ‘Almost always/Always’. The BIS consists of three second-order factors that are labeled Attentional Impulsiveness, Motor Impulsiveness, and Nonplanning Impulsiveness. Cronbach’s α coefficient for the whole scale was 0.77.

Dietary restraint

To measure restrained eating we used a Dutch translation of the restraint scale (RS; Herman & Polivy, 1980). The RS consists of 10 items assessing individuals’ weight fluctuations and concern with dieting. Higher scores on the RS indicate that individuals are chronically, unsuccessfully, dieting and have difficulty controlling their food intake under a variety of conditions (Stice, Presnell, Lowe, & Burton, 2006). Cronbach’s α coefficient was 0.75.

Data analyses

Before performing our main analyses, one-way ANOVAs were performed on baseline variables (age, BMI, restrained eating, time since last eaten, and impulsivity) to determine whether there were differences between the experimental groups. Correlational analyses were used to examine the relations among participants’ scores on the above-mentioned variables and food intake. Significant relationships were controlled for in all future analyses. An ANCOVA was used to examine the interaction between the two conditions (cue exposure \times duration) on food intake. Hierarchical linear regression analyses were used to test the other interactions of the cue exposure condition with continuous variables (impulsivity and dietary restraint) on food intake and saliva secretion (when entering the test room). Impulsivity was treated as a continuous measure because this has several advantages, such as higher estimates of effects size, higher power without overestimation of strength of relationship, and a reduced risk of type I errors (Maxwell & Delaney, 1993). Continuous variables were centered prior to entering in the analysis. For the dichotomous condition variables we used a 0 vs. 1 coding scheme. The predictor variables were entered into the analyses in the following order: potential covariates (step 1), main effects of conditions and impulsivity (step 2), and the interaction between cue exposure condition and impulsivity (step 3). Combined two- and three-way (cue \times duration \times impulsivity or cue \times impulsivity \times restraint) interactions were also tested. Post hoc probing of significant moderator effects were conducted according to Holmbeck (Holmbeck, 2002). Data

from post hoc probing were used to generate regression lines for the variables of interest. For the participants who were in the long-term conditions, we also calculated repeated measures analyses of variance on the eight saliva measurements with condition (smell cue present vs. absent) as between-subject factor. Greenhouse-Geisser correction was applied when sphericity was violated. Statistical significance was set at $p < .05$. Data were analyzed using SPSS for Windows (version 15.0, 2006, SPSS Inc, Chicago, IL).

Results

Differences between the two cue exposure groups and correlations

We first checked whether participants in the various conditions differed with respect to BMI, age, time since last eaten, and dietary restraint. Table 1 shows the characteristics of participants in the different conditions. Participants in the different conditions did not differ on BMI, age, dietary restraint, impulsivity, and number of minutes since last time eaten (all p 's $> .10$), implying that randomization over the conditions was successful.

Table 2 shows the correlations of all our model variables. BMI, age, and dietary restraint were not significantly correlated with participants' intake and therefore not included in the model as potential confounds. However, the last time participants had eaten (in minutes) was positively related to the amount of food consumed, $r(108) = .30$, $p < .01$, and inversely related to the amount of saliva produced when entering the test room, $r(107) = .23$, $p < .05$. Therefore, time since last eaten was included in our regressions as a potential confound.

Impact of conditions and participants' impulsivity on food intake

Neither olfactory cue exposure ($F_{1,104} = .61$, $p = .44$) nor duration of the exposure ($F_{1,104} = .74$, $p = .39$) had a main effect on participants' food intake. Table 1 shows the total amount consumed (in kcal) in the various conditions. No interaction was found between olfactory cue exposure and duration ($F_{1,104} = .28$, $p = .60$). However, a significant interaction effect was found (depicted with regression) between the olfactory cue exposure condition and impulsivity ($\beta = -.31$, $p = .026$), after controlling for the last time participants had eaten (see Table 3). The interaction remained significant in a reduced model with only the olfactory cue exposure condition, impulsivity scores, and the interaction between these variables. To clarify this interaction, post-hoc analyses were conducted. Significant moderator effects were explored by comparing simple slopes for values of impulsivity scores $\pm 1SD$. These analyses revealed no effect of the cue exposure conditions on food intake for females with high impulsivity scores, $t(104) = -.91$, $p = .37$. However, a significant effect of the cue exposure conditions was found for females with low impulsivity scores, $t(104) = 2.05$, $p = .04$. Thus, only the participants with low impulsivity scores were significantly influenced by the cue exposure conditions, and ate more when confronted with the odour of baked cookies. Figure 1 shows the interaction depicted for the $\pm 1SD$ impulsivity scores. We repeated these analyses for established cut-offs for low and high BIS scores in college samples -i.e., scores of 52 and 72, respectively- and this led to equivalent results.

Additional analyses with dietary restraint and BMI

We also examined potential 2 and 3-way interactions of the cue exposure conditions and/or impulsivity with dietary restraint. However, none of the tested interactions were significant.

Impact of olfactory cue exposure condition and impulsivity on saliva secretion

Table 3 shows the results of the hierarchical regression analysis with saliva secretion when entering the test room as dependent variable. Neither olfactory cue exposure nor impulsivity or the interaction between cue exposure and impulsivity were significantly related to saliva secretion. The amount of saliva secretion in the various conditions when entering the test room is shown in Table 1. Figure 2 shows all saliva trials for the long-term conditions. Repeated measures analyses showed a significant decline in saliva secretion over time ($F_{1,49} = 3.93$, $p < .01$). There was, however, no effect of cue exposure condition ($F_{1,49} = .02$, $p = .89$) or cue exposure condition \times impulsivity ($F_{1,49} = .17$, $p = .69$) on overall salivation level or on saliva decline over time (cue exposure \times time: $F_{1,49} = .59$, $p = .65$ and cue exposure \times impulsivity \times time ($F_{1,49} = 1.38$, $p = .25$).

Discussion

In contrast to our expectations, the present study found that the effects of olfactory food-cue exposure on the amount of food intake did not depend on the contextual duration of food-cue exposure. Although trait impulsivity moderated the impact of cue exposure on intake, results were contrary to our expectations. Low-impulsive females consumed more, but did not salivate more, when confronted with an olfactory food cue than when confronted with no food cue. For highly impulsive females, food-cue exposure affected neither the amount of saliva flow nor the amount of food consumed; the same was true for impulsive restrained eaters. Although a decreasing pattern of saliva flow was found in the long-term duration condition, cue exposure and impulsivity did not influence this effect. Our findings may be explained by the fact that we did not instruct our participants to pay attention to the olfactory food cue.

We expected young women to eat less when they were confronted with food cues for a prolonged time and eat more when confronted to short-term food cues. We did not find support for these hypotheses. The cue exposure did not impact food intake in normal-weight females in either the short-term or long-term cue exposure group (or for unrestrained eaters). In contrast, two previous studies (Jansen et al., 2003; Rogers & Hill, 1989) found that prolonged food-cue exposure decreased food intake among normal-weight children (Jansen et al., 2003) and unrestrained females (Rogers & Hill, 1989). In these previous within-subjects studies, participants had to focus on a visible olfactory food cue (foods held directly under participants' noses, so participants had to smell the food intensely). Our contrasting results may thus be the result of differences in design (within- vs. between-subjects), the visibility of the food cue, the amount of cue focus, or a combination of these factors. Two other between-subjects experiments in which participants had to focus on a prolonged visible olfactory food cue did not find significant effects on food intake (Jansen & van den Hout, 1991; Nederkoorn & Jansen, 2002). However, sample sizes in these studies were small and, in terms of effect sizes, moderate effects were found (Cohen's d -0.50 and -0.58), with unrestrained females eating less after confrontation with the food cue. As in our study, studies in which participants were not instructed to pay explicit attention to the prolonged food cue (visible or not) also found no notable impact of the cue manipulation on food intake among unrestrained females (Coelho, Jansen et al., 2009; Coelho, Polivy et al., 2009; Fedoroff et al., 1997; Fedoroff et al., 2003). One previous study suggested that focused attention to a short-lived food cue increases consumption (Cornell et al., 1989). Overall, these findings may suggest that the amount of focus

Table 1
Means (standard deviation) of all variables.

	Smell present and short-term (n = 28)	Smell present and long-term (n = 30)	Smell absent and short-term (n = 27)	Smell absent and long-term (n = 24)	Total group (N = 109)
Age	20.96 (1.89)	21.25 (2.63)	20.41 (2.27)	21.17 (1.52)	20.94 (2.14)
BMI	21.42 (1.86)	21.43 (1.57)	22.11 (1.61)	21.48 (1.57)	21.61 (1.66)
Minutes since last time eaten	193.82 (30.14)	208.07 (91.86)	208.89 (69.54)	224.38 (74.50)	208.20 (70.36)
Dietary restraint	8.76 (4.27)	7.84 (4.57)	9.92 (4.66)	10.32 (4.08)	9.13 (4.46)
Impulsivity	64.57 (9.38)	66.11 (8.84)	63.92 (7.98)	64.96 (9.36)	64.92 (8.81)
Saliva measure after entering the room	0.71 (0.54)	1.05 (0.88)	0.94 (0.61)	0.98 (0.84)	0.93 (0.74)
Food intake (in kcal)	162.04 (89.81)	167.03 (55.42)	142.70 (78.91)	163.26 (80.92)	158.82 (76.49)

paid to the food cue is an important determinant influencing intake.

In addition to food intake, salivary flow was also not influenced by the cue exposure. Although we measured saliva flow as an index of underlying cue reaction, it was not related to food intake. We found a decreasing pattern of saliva flow over time; however, this pattern counted similarly for both the “cue present” and “cue absent” (control) group. This suggests that our participants did not habituate to the food cue and that the decreasing saliva pattern that was found is the result of receptor or effector fatigue (Thompson & Spencer, 1966). In a standard habituation design, the participant’s attention is focused on the food cue. We suggest that, if we had let participants focus on the food cue, we would have found a faster decrease in saliva flow after food-cue exposure. Thus far, previous habituation studies lack “cue-absent” control groups, but have consistently shown that the salivary response to food-cues habituates and dishabituates after novel stimuli (Epstein, Rodefer, Wisniewski, & Caggiula, 1992) is delayed or absent among obese individuals (Bond, Raynor, McCaffery, & Wing, 2010; Epstein, Paluch, & Coleman, 1996) and blocked by the presentation of food variety or distractors (Epstein, Paluch, Smith, & Sayette, 1997; Temple, Giacomelli, Roemmich, & Epstein, 2008), supporting the idea that the allocation of attention can influence cue reactivity.

The fact that we did not instruct our participants to pay explicit attention to the olfactory food cue may also explain our reversed impulsivity finding for food intake. Although in the present study, low-impulsive females consumed more energy when confronted with the olfactory food cue, they did not show increased saliva secretion, indicating that it is unlikely that (the lack of) habituation accounted for this food intake effect. However, previous research has shown that people are generally not consciously aware of the impact of external food cues on their food intake (Vartanian, Herman, & Wansink, 2008), which probably also accounts for olfactory cues. Low-impulsive people may be more easily affected by less-explicit cues as exerting control over relatively automatic affective reactions that occur without conscious awareness is rendered difficult. Because high-impulsive people have a stronger attentional

Table 2
Pearson’s correlations between all variables.

	1	2	3	4	5	6
1 Age	–					
2 BMI	.05	–				
3 Minutes since last time eaten	–.03	.16	–			
4 Dietary restraint	.05	.43**	.14	–		
5 Impulsivity	–.10	–.04	.08	.07	–	
6 Food intake (in kcal)	–.05	.11	.30*	–.09	.03	–
7 Saliva measure after entering the test room	.09	–.19	–.23*	.07	–.08	.10

* p < .01.
** p < .001.

bias for food cues (Hou et al., 2011), they might have been more focused on the potential impact of the less explicit sensory cue, which may have facilitated the subsequent use of voluntary avoidance strategies to resist overconsumption. Overweight people show a characteristic pattern of initial automatic orientation toward food cues and a subsequent voluntary attentional shift away from food (Werthmann et al., 2011). Considering the link between obesity and impulsivity (Braet et al., 2007), future research should examine whether this same “approach-avoidance” pattern might also count for impulsive people. In contrast to our study design, Jansen et al. (2009) instructed participants to smell the cookies intensely and to pretend they were eating the cookies. They found higher intake patterns among high-impulsive, high-restrained females. The more explicit sensory cue used in Jansen et al. (2009) may have exerted contrary controlling effects. Low-impulsive people who are generally over-controlled might be better able to control their affective reactions in response to explicit sensory cues. However, this explicit focus might have made it more difficult for high-restrained, high-impulsive people to control eating by complicating the use of avoidance strategies. Here, habituation may have been one of the underlying mechanisms responsible for these results. Future research should examine whether high-impulsive, high-restrained individuals show decreased or absent salivary habituation to food cues.

Previous research suggests that the way in which the food cue is presented is a critical factor in determining eating behavior among people with highly restrained eating tendencies (Coelho, Jansen et al., 2009). High-restrained individuals were found to eat more only after exposure to a salient sensory eating cue to which they had been explicitly paying attention; they did not eat more after exposure to a less salient sensory eating cue (Coelho, Jansen et al., 2009). It would be of interest for future studies to test whether and how the interaction of impulsivity—especially when

Table 3
Hierarchical regression analysis: main effects and moderating impulsivity effect on food intake and saliva secretion (when entering the test room).

Step		Food intake		Saliva secretion	
		β at entry	R ² adjusted	β at entry	R ² adjusted
1	Minutes since last time eaten	.30**	.083**	–.23*	.042*
2	Cue exposure condition	.12	.075	–.08	.043
	Duration condition	.05		.14	
	Impulsivity	–.01		–.07	
3	Cue exposure condition × impulsivity	–.31*	.110*	.01	.033

Note: For food intake: neither the 2-way interaction between cue exposure × duration, nor any of the other 2-way or 3-way interactions between cue × duration × impulsivity or cue × impulsivity × restraint was significant.

* p < .05.
** p < .01.

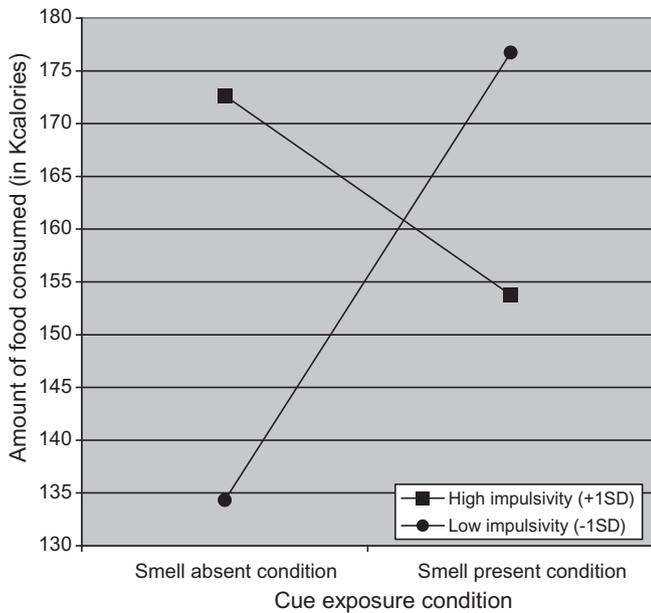


Fig. 1. Regression lines for relations between cue exposure conditions and food intake as moderated by impulsivity.

combined with dietary restraint—with sensory food cues is determined by the way in which the food cue is presented. Future research may also experimentally manipulate the awareness of low-impulsive people to less explicit food cues to determine how this affects their food intake.

An additional explanation that may underlie the finding that our smell manipulation affected only low-impulsive females is that we used a self-report questionnaire to assess the controlling aspect of (trait) impulsivity, whereas the earlier study (Jansen et al., 2009) used a response inhibition task (state impulsivity). It is possible that the reflecting controlling trait aspects may be particularly counteracted when participants are confronted with less explicit sensory eating cues that they are not aware of. Future research may further examine whether and how these different controlling aspects of impulsivity interact with different real-world sensory food cues. For instance, impulsive people might be more vulnerable to sensory

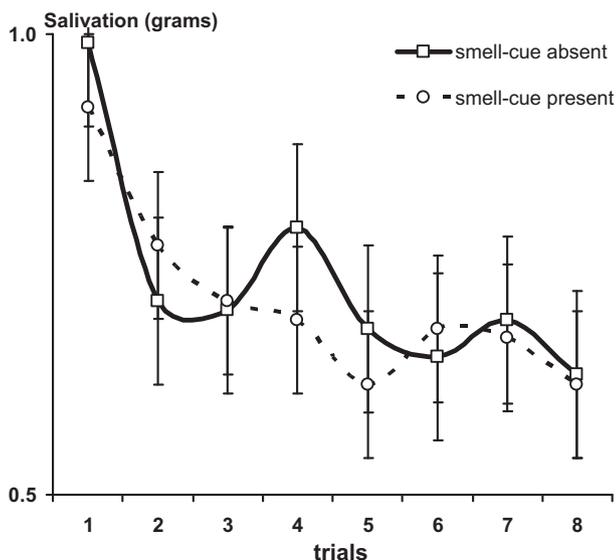


Fig. 2. Mean (SEM) salivation over eight salivation trials in a group without olfactory food-cue exposure being present or not.

food cues that operate during the eating process (e.g., how the food looks and the taste of food); this vulnerability may increase their general consumption.

The extent to which food cues elicit automatic associative reactions is probably not the same for all people. Highly reward-sensitive people detect more rewarding stimuli (e.g., food) and are more likely to approach these stimuli. Previous research has shown that reward-sensitive persons display increased fast food intake when exposed to more neighborhood fast food restaurants (Paquet et al., 2010). Similarly, in an experimental study, reward sensitivity interacted with food variety: More reward-sensitive children consumed more calories than less reward-sensitive children only when exposed to a variety of foods (Guerrieri et al., 2008). Recent research has shown that inhibitory control moderates the influence of automatic snack food preference on the amount of food eaten (Hofmann, Friese, & Roefs, 2009) and weight gain (Nederkoorn et al., 2010). Future research may benefit from using a dualistic model approach focusing on the combination of trait reward and control systems in the interaction with environmental eating cues.

A few limitations warrant discussion. First, we used a traditional taste-test paradigm to test the amount of food consumed. Although this paradigm has often been used to measure the amount of food consumed in interactions with food cues, it may not be the best example of a natural eating situation. It would be interesting to observe young women's food intake when confronted with food cues in daily-life settings, such as a restaurant or canteen. Second, we lack information on whether people noticed the aroma of the cookies and, if they did, whether they paid attention to the food cue. Because the cookies were baked in the test room itself, it is unlikely that participants did not smell the cookies. However, we assume that they paid less attention to this food cue because we did not instruct participants to focus on it. In addition, participants might have been distracted because it is not appetizing to keep dental rolls in one's mouth. Although the absorption of saliva using rolls of cotton is an easily and frequently used reliable method, there are some adverse aspects of this procedure for appetite research (Nederkoorn, de Wit, Smulders, & Jansen, 2001). Future studies may compare food intake effects of different olfactory cues according to their extent of focus and may examine salivary flow using counting swallows (Nederkoorn et al., 2001) as an explanatory mechanism for the potentially different results found. Finally, this study focused exclusively on female university students, restricting the generalizability of the current findings. Future studies should also examine how impulsivity interacts with sensory food cues in males, children, or older adults from a more diverse social and educational background.

Since the "obesogenic" environment in which people live is often blamed for the rise in overweight and obesity, it is important to gain insights into why and under what conditions people's food intake is affected by environmental stimuli. We found that the duration of our less-explicit food-cue exposure did not impact food intake. If future research demonstrates that short-term food cues increase and prolonged food cues decrease food intake under the conditions of heightened cognitive cue attention, it might suggest that—to prevent overeating—it is generally better to ignore short-term food cues and pay explicit attention to prolonged food cues. However, our study demonstrates that low impulsive normal-weight females consumed more food when confronted with an olfactory food cue to which no explicit attention was paid. This suggests that these daily life olfactory food cues in particular determine overeating in people who are normally well controlled. This finding may suggest that exposure and response prevention could not only serve as a useful tool to prevent overeating in overweight or obese individuals, but may also be helpful for normal-weight individuals who are normally well controlled and who might be at risk for becoming overweight.

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