Physiology & Behavior 133 (2014) 190–196

Contents lists available at ScienceDirect

Physiology & Behavior

journal homepage: www.elsevier.com/locate/phb

Food preference and intake in response to ambient odours in overweight and normal-weight females

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HIGHLIGHTS

- We study effects of (food) odours alone using ambient exposure.
- We focus on relevant measures of food-cue responsivity (preference & intake).
- We explore key factors in eating behaviour: BMI, hunger and energy density signals.
- Hungry women show higher food intake and preference for energy dense food products.
- In the current setting, ambient odours did not affect food preference and intake.

ARTICLE INFO

Article history:
Received 5 December 2013
Received in revised form 4 April 2014
Accepted 7 May 2014
Available online 29 May 2014

Keywords:
Odor
Food cue
Overweight
Hunger
Food preference
Energy intake

ABSTRACT

In our food abundant environment, food cues play an important role in the regulation of energy intake. Odours can be considered as external cues that can signal energy content in the anticipatory phase of eating. This study aims to determine whether exposure to olfactory cues associated with energy dense foods leads to increased food intake and greater preference for energy-dense foods. In addition, we assessed whether BMI and hunger state modulated this effect.

Twenty-five overweight (mean BMI: 31.3 kg/m^2, S.E.: 0.6) and 25 normal-weight (mean BMI: 21.9 kg/m^2, S.E.: 0.4) females, matched on age and restraint score, participated. In 6 separate sessions they were exposed to odours of three different categories (signalling non-food, high-energy food and low-energy food) in two motivational states (hungry and satiated). After 10 min of exposure food preference was assessed with a computerized two-item forced choice task and after 20 min a Bogus Taste Test was used to determine energy intake (kcal and g).

In a hungry state, the participants ate more ($p < .001$) and preferred high-energy products significantly more often ($p < .001$) when compared to the satiated state. A trend finding for the interaction between hunger and BMI suggested that the food preference of overweight participants was less affected by their internal state ($p = .068$). Neither energy intake (kcal: $p = .553$; g: $p = .683$) nor food preference ($p = .280$) was influenced by ambient exposure to odours signalling different categories.

Future studies need to explore whether food odours can indeed induce overeating. More insight is needed regarding the possible influence of context (e.g. short exposure duration, large variety of food) and personality traits (e.g. restraint, impulsive) on odour-induced overeating.

1. Introduction

The sensory properties of food, such as the sight and smell, are important factors for regulating what and how much we eat [5,36]. Such food cues are omnipresent in our food abundant environment. When walking through a random shopping street you most likely encounter the sight of delicious burgers and the smell of sweet pastry. Food cues may provide information about the nutritional consequences related to the food they signal as we have learned to associate them with the postingestive effects after frequent combined exposure [1]. Mere exposure to these food cues may activate cephalic phase responses (e.g. salivation, gastric activity) that prepare the gastro-intestinal tract for better absorption of nutrients [22,25,34]. This may stimulate food craving and intake [4,16].

Together with the sensory properties of food, internal signals related to metabolic state play an important role in determining food preference and intake [24,29,43]. Metabolic state can modulate hedonic responses to the sensory properties of food and can thereby stimulate energy intake in a state of high energy demand (hunger). Findings of

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http://dx.doi.org/10.1016/j.physbeh.2014.05.026
0031-9384/

Jiang et al. [19] demonstrated that hedonic ratings of visual and olfactory food cues decrease after food intake. The strength of this effect is proposed to be dependent on the average hedonic values of food categories [2]. Highly palatable and energy dense foods (e.g. ice cream, chocolate, cake and pie) received higher hedonic ratings in a hungry state, whereas ratings for low energy products such as fruits did not differ between metabolic states [19]. Food preference has been considered as the outcome of the hedonic value of the foods, the metabolic state and the context [23]. Altogether, it appears that the interplay between internal hunger cues and external food cues may influence the attitude towards food (hedonic ratings, preference). However, the interaction effect of the two factors has not been widely investigated and it is at present unclear how these factors affect actual food intake.

Eating behaviour of overweight people is thought to be less directed by internal cues, as these can be easily overruled by external cues [13,32]. A heightened cephalic phase response to palatable food cues in our food abundant environment may contribute to overeating and overweight. Ferriday et al. [10] already demonstrated that the motivation to consume food after exposure to the sight and smell of pizza was higher in overweight compared to lean individuals. BMI was found to positively affect portion size selection of visual and olfactory cued food [38]. Moreover, differences in actual food intake after cue exposure have been shown as well. Food intake during a Bogus Taste Test was marginally higher in overweight children after intensely smelling a food that was put in front of them than after a non-food control condition, whereas it was lower in normal-weight children [18]. On the other hand, pizza intake (g), after 1 min of pizza odour exposure, did not differ significantly between normal-weight and overweight participants in the study of Ferriday et al. [10].

If food cues indeed signal the body to gear up for optimized ingestion of food, it would not be surprising if this is directed towards the intake of specific food categories or products. Appetite for a product may not only be stimulated or suppressed by external cues that are related to the product category, but also by cues that are specific to the product. Rolls and Rolls [30] demonstrated that signs of satiety for a specific product occur after smelling their respective odour. They found that pleasantness ratings for banana and chicken odours decreased after 5 min of smelling a plastic cup containing banana or chicken, respectively. Recently, a similar study found opposing evidence for increased appetite specific to products that were cued by ambient odours [27]. Even though pleasantness of the odour and appetite for a product are not the same thing, it is plausible that odour exposure would modulate such ratings in the same direction. Perhaps the opposing effects can be explained by the fact that smelling odour-filled cups is more conscious, whilst ambient odour exposure represents a more implicit and realistic way of experiencing odours.

Previous research into the effects of food cues has often used a combination of visual and olfactory cues (e.g. [10,18]), or used 'artificial' methods of smelling (e.g. [30]). Independent from visual food cues, food odours alone might also lead to physiological responses that prepare for food intake. Although anecdotal evidence does suggest an important contribution of food odours to the regulation of energy intake, there is currently insufficient scientific evidence to substantiate these reports. Studies that have looked into behavioural responses to food cues mainly use subjective ratings (e.g. [10,27,30,38]). These ratings may provide some indication about food preferences, but they may not represent actual food choice and intake. Research into the effects of olfactory food cues on actual eating behaviour is scarce. Larsen et al. [21] examined this, but did not find an effect of ambient cookie odour exposure on cookie intake. Additionally, in order to learn more about odour-induced overeating in our food abundant environment, it is important to use experimental set-ups that mimic odour exposure as it occurs in a natural context.

To get a better grip on the complex issue of overeating, the mechanisms behind actual food intake regulation need to be clarified. In this study we explore a combination of several key factors: hunger state, BMI and energy density of the food cue. By examining the effects of food odours alone with a more naturalistic method of odour exposure (ambient exposure) the current study provides new information on ecologically relevant food-cue responses. Our primary interest was to determine the effect of different categories of olfactory cues (signalling high-energy food, low-energy food and non-food) on eating behaviour (food preference and intake). In addition, we were interested whether this effect would be modulated by BMI and hunger state. Exposure to an odour of an energy-dense food product was expected to lead to an increased food intake and a stronger tendency to choose high-energy products. We hypothesized that this effect would be more pronounced in the overweight participants and that hunger state would influence food-cue responses less in overweight than in normal-weight individuals.

2. Methods

2.1. Overall design

This study followed a 2 × 2 × 3 mixed model cross-over design, including BMI group (overweight; normal-weight) as a between-subject factor and hunger state (hungry; satiated) and odour category (signalling high-energy food, low-energy food and non-food) as within-subject factors (see Table 1).

2.2. Participants

Twenty-five overweight (mean BMI: 31.3 kg/m^2, S.E.: 0.7) and 25 normal-weight (mean BMI: 21.9 kg/m^2, S.E.: 0.4) females participated in this study. They were matched on age (mean: 33, S.E.: 1.6) and restraint score (mean: 3.0, S.E.: 0.1). Restraint score (1–5) was determined by using an online version of the restraint subscale of the Dutch Eating Behaviour Questionnaire (DEBQ; [40]). Higher scores indicate higher dietary restraint. Inclusion criteria were: weight stable for at least 6 months, no psychological or physical abnormalities or use of medication that could influence their sense of smell, eating behaviour or body weight. Individuals who met the inclusion criteria were invited for a screening session at Wageningen University.

During the screening session, BMI (kg/m^2) was measured. Individuals that were either normal-weight (BMI: 18.5–25 kg/m^2) or overweight (BMI >27 kg/m^2) were included. Further, individuals were tested with the identification part of the Sniffin' Sticks task to ensure that they were normosmic (≥75% correct; [15]).

In order to keep the participants naïve to the actual goal of the study (to study the effect of odour exposure on eating behaviour), they were informed that the study was aimed at assessing differences in the pleasantness ratings for several types of sandwich spreads between overweight and normal-weight participant. All the participants provided written informed consent before entering the study. This study complied with the rules and regulations of the Medical Ethical Committee of Wageningen University and was executed in accordance with the ethical principles of the Declaration of Helsinki (2008).

2.3. Olfactory stimuli

In six separate sessions the participants were exposed to ambient odours of three different categories; signalling either high-energy food (HE), low-energy food (LE) and non-food (NF). Test sessions were conducted with two different odour sets since we were interested in odour category effects instead of effects of specific odours (see Table 1). One set included sweet odours: Dark Chocolate (HE; IFF 10810212; 5% in Propylene Glycol (PG)), Strawberry (LE; IFF 10809989; 6% in PG) and Fresh Green (NF; AllSens No. 819; 2% in PG); and the other set included savoury odours: Peanut (HE; IFF 15038990; 3% in PG), Cucumber (LE; IFF 15032189; 100%) and Wood (NF; AllSens No. 821; 10% in PG). The participants were randomly assigned to one of the two odour sets. Because we were not interested in the specific effects of sweet and