Appetite 117 (2017) 255–262

Contents lists available at ScienceDirect

Appetite

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

Visual food cues decrease postprandial glucose concentrations in lean and obese men without affecting food intake and related endocrine parameters☆

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ARTICLE INFO

Article history:
Received 16 March 2017
Received in revised form
9 June 2017
Accepted 4 July 2017
Available online 5 July 2017

Keywords:
Visual cues
Food pictures
Food intake
Glucose homeostasis
Cephalic phase response
Anticipation

ABSTRACT

The abundance of highly palatable food items in our environment represents a possible cause of overconsumption. Neuroimaging studies in humans have demonstrated that watching pictures of food increases activation in brain areas involved in homeostatic and hedonic food cue processing. Nevertheless, the impact of food cues on actual food intake and metabolic parameters has not been systematically investigated. We tested the hypothesis that watching high-calorie food cues increases food intake and modifies anticipatory blood parameters in lean and especially in obese men. In 20 normal-weight and 20 obese healthy fasted men, we assessed the effects of watching pictures of high-calorie food items versus neutral contents on food intake measured during a standardized test buffet and subsequent snacking as well as on glucose homeostasis and endocrine parameters. Compared to neutral pictures, viewing food pictures reduced postprandial blood glucose concentrations in lean ($p = 0.016$) and obese ($p = 0.044$) subjects, without any differences in insulin or C-peptide concentrations (all $p > 0.4$). Viewing food pictures did not affect total calorie intake during the buffet (all $p > 0.5$) and snack consumption (all $p > 0.4$). Concentrations of ghrelin, adrenocorticotropic hormone (ACTH), cortisol, and glucagon also remained unaffected (all $p > 0.08$). These data indicate that preprandial processing of food cues curbs postprandial blood glucose excursions, without immediately affecting eating behavior in normal-weight and obese men. Findings indicate that exposure to food cues does not acutely trigger calorie overconsumption but rather improves the glucoregulatory response to food intake.

1. Introduction

The current obesity epidemic is a major problem for health care. The abundance of high-calorie food, rich in sugar and fat, may contribute to overconsumption and development of overweight. Moreover, pictures of palatable foods shown e.g. for advertising purposes are a ubiquitous part of everyday life in western societies (Mink, Evans, Moore, Calderon, & Deger, 2010). Exposure to food (slices of pizza) in the laboratory has been demonstrated to increase rated desire to eat this particular food in both men and women (Marcelino, Adam, Couronne, Koster, & Sieffermann, 2001). Furthermore, showing food pictures increased the size of pizza portions normal-weight women intended to eat as well as subsequent actual intake, suggesting that food cues increase the amount of food that people will consume (Ferriday & Brunstrom, 2008). In contrast, a recent study in women failed to demonstrate any stimulating effects of food pictures on snack intake (van Nee, Larsen, & Fisher, 2016).

Neuronal effects of exposure to food cues have been examined in studies using functional magnetic resonance imaging (fMRI). Watching food pictures activates a large bilateral brain network

Abbreviations: cephalic phase insulin release, CPIR.
☆ This work has not been peer-reviewed previously.
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http://dx.doi.org/10.1016/j.appet.2017.07.001
0195-6663/

which is typically involved in food cue processing (Kroemer et al., 2013b). Visual cues of high-fat food stimulate neural circuits engaged in energy homeostasis and reward processing, like the hypothalamus and the striatum, in healthy lean women (Schur et al., 2009). In contrast to lean women, obese women react to high-calorie food cues in particular with an activation of the dorsal striatum, a brain region involved in reward anticipation and habit learning (Rothemund et al., 2007).

Visual food cues also affect metabolic and endocrine parameters. The sight of appetizing food was sufficient to increase gastric acid and serum gastrin levels (Feldman & Richardson, 1986) and, moreover, to increase the concentrations of the orexigenic hormone ghrelin (Schussler et al., 2012). These anticipatory changes in metabolism are regarded as cephalic phase responses, i.e. metabolic reflexes whose afferent signals originate in the head and which are thought to prepare the body for the processing of absorbed nutrients (Power & Schulkin, 2008).

In our study in lean and obese men, we investigated the effects of watching pictures of food or non-food items on hunger- and reward-driven eating behavior by analyzing calorie intake from a standardized test buffet (including the analysis of separate macronutrients) and a subsequent snack test (with three different types of cookies). Furthermore, we scrutinized blood glucose and blood parameters of energy metabolism as well as subjective mood, hunger and the desire to eat. We tested the hypotheses that watching high-calorie food cues increases food intake from the test buffet and the snack test as well as ratings of hunger and the desire to eat. Because mood and impulsivity might affect food intake, these variables were measured using questionnaires. In addition, because food cues might affect glucose metabolism by increasing anticipatory responses such as ghrelin and insulin/C-peptide, we measured the glucoregulatory hormones ACTH, cortisol, and glucagon. We expected the stimulatory effect of food cues to be observable in lean men and – to an even greater extent – in obese men. In a supplementary experiment, the same food items were both visually presented as food cues and subsequently offered for actual consumption, inasmuch as recent studies have stressed the importance of this aspect (Blechert, Klackl, Miedl, & Wilhelm, 2016).

2. Subjects and methods

Subjects. Twenty normal-weight and twenty obese healthy men participated in the study (mean age ± SEM, 24.1 ± 3.7 vs. 25.2 ± 3.7 years, $p \geq 0.35$; BMI, 22.4 ± 1.5 vs. 34.9 ± 3.6 kg/m^2, $p < 0.001$). Sample size was calculated with G*Power (version 3.1.9.2) according to previous studies on related effects on food intake and endocrine parameters (Kroemer et al., 2013a; Ott et al., 2013). Body composition was assessed by bioelectrical impedance analyses (Nutriguard-M, Data Input, Darmstadt, Germany) at the start of each experimental session. Body composition was different between both weight groups with regard to lean body mass ($F(1,35) = 51.98$; $p < 0.001$ for between-subjects comparisons) and fat mass ($F(1,35) = 76.68$; $p < 0.001$), but remained comparable across conditions (both $p > 0.4$ for "condition"). In detail, obese compared to lean participants had more body fat (39.44 ± 2.61 kg vs. 13.78 ± 0.79; $p < 0.001$) and lean body mass (79.32 ± 1.78 kg vs. 61.75 ± 1.61; $p < 0.001$). The health of participants was evaluated by clinical examination, medical history including abuse of alcohol, nicotine or any drugs, and routine laboratory tests during screening. All participants submitted written informed consent and the study was approved by the ethics committee of the University of Lübeck, Germany.

Experimental procedure of the main experiment. Experiments were carried out in the Center for Brain, Behavior and Metabolism at the University of Lübeck, Germany during August 2014 and February 2016. They were performed in a within-subject comparison. Each participant attended two different conditions (food pictures vs. non-food (neutral) pictures). There was a 14-day interval between sessions with the order of conditions balanced across subjects. All subjects were instructed to be fasted (with exception of drinking water) after 2200 h on the day preceding each session.

Participants arrived at the lab at 0900 h. After a brief history and physical examination, a venous cannula was inserted into the non-dominant lower arm or cubital fossa to enable blood sampling during experiments. Blood was sampled at 0950 h for baseline assessments of hormonal parameters and blood glucose, as well as at defined intervals throughout the session. As a cover story, participants were told that the experiment aimed at investigating the impact of visual cues on gustatory perception, tested at the end of the experiment by gustatory questionnaires referring to the implemented snack test. At 1010 h and 1130 h (just before the test buffet and the snack test), a set of 50 pictures of food items or – in the other condition – non-food items was shown on a notebook computer. Each picture was displayed for ten seconds, amounting for eight minutes and twenty seconds for the whole set of pictures. This set comprised high-resolution images of food from a standardized database, showing high-calorie meals (caloric values rated above > 300 kcal for each of the items), e.g. chocolate cake, pasta or ice-cream. Neutral images originated from the database of Brooks and colleagues and depicted non-food items like books or pencils (Brooks et al., 2011).

Immediately after watching the picture set, participants ate from an ad libitum test buffet until satiated. Without the knowledge of participants, the offered food was weighed before and after the test buffet to assess spontaneous food intake in the fasted state. The test buffet consisted of bread rolls, brown bread, cheese, smoked salmon, meat salad, salami, cream cheese, butter, chocolaty hazelnut spread, meatballs, potato chips, peanuts, chocolate, muffins, wine gums, custard, lemonade, chocolate-flavored milk, orange juice, condensed milk, sugar, fruit tea, coffee (decaffeinated), and water (about 10,000 kcal were offered; Supplemental Table 1). After the second run of picture exposure at 1130 h, subjects underwent a snack test with three different types of snacks (salty, sweet and neutral) in a paradigm addressing the hedonic component of eating behavior in the relative absence of hunger (Hallschmid, Higgs, Thienel, Ott, & Lehnert, 2012; Higgs, Williamson, & Attwood, 2008). Here, participants filled out questionnaires assessing their gustatory perception with ratings of the items "salty", "sweet", and "sour" for different snacks, so that our cover story was corroborated. Again, subjects were instructed to eat as much as they like and total intake of macronutrients in kilocalories was protocolled.

Mood was rated on the Multidimensional Mood Questionnaire on a 5-point scale containing items of the categories good/bad mood, alertness/sleepiness, and calmness/agitation (Hinz, Daig, Petrowski, & Brahler, 2012). For the assessment of subjective feelings of hunger, satiety, or desire to eat something sweet or savory, visual analogue scales (0–100 mm) were used (Flint, Raben, Blundell, & Astrup, 2000). Participants performed the set of questionnaires at five times in each session (0940 h, 1025 h, 1110 h, 1145 h and 1210 h).

To assess impulsivity, participants performed a 27-item Monetary Choice Questionnaire (MCQ) at the end of each session (1215 h), which measures delayed discounting by asking individuals to choose between smaller rewards available immediately and larger rewards available after a delay (Gray, Amlung, Palmer, & MacKillop, 2016; Kirby, Petry, & Bickel, 1999). Individual indifference points were determined and discounting rates