



Research report

Orofacial reactivity to the sight and smell of food stimuli. Evidence for anticipatory liking related to food reward cues in overweight children [☆]Robert Soussignan ^{a,*}, Benoist Schaal ^a, Véronique Boulanger ^a, Marie Gaillet ^a, Tao Jiang ^{b,*}^a *Developmental Ethology and Cognitive Group, Centre des Sciences du Goût et de l'Alimentation, CNRS (UMR 6265), Université de Bourgogne, 1324 INRA, 9E boulevard Jeanne D'arc, Dijon, France*^b *Centre de Recherche en Neurosciences de Lyon, CNRS (UMR 5292), Université Claude Bernard Lyon 1-INSERM 1028, Lyon, France*

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ABSTRACT

Whether food liking may be a risk factor of overconsumption and overweight/obesity remains a controversial issue. So far, most studies used subjective reports to assess consummatory behavior, approaches that might overlook subtle or implicit hedonic changes to sensory properties of foods. Therefore, we used a cue-exposure approach by recording different measures of hedonic processes (orofacial reactivity, self-rated pleasantness, food preference) in 6–11 years old overweight ($n = 20$) and normal-weight ($n = 20$) children. Children were exposed to the *smell and sight* of high and low-energy density food stimuli and to non-food stimuli during pre- and post-prandial states. Their facial and verbal responses were videotaped and parent's reports of children's eating styles and appetitive traits were collected using the Children's Eating Behavior Questionnaire (CEBQ). Results showed that orofacial reactivity, as an objective measure of anticipatory liking, was more discriminative than self reports, with overweight children displaying more lip sucking than normal-weight children when exposed to high energy food pictures and to food odorants. Orofacial reactivity to food cues was also associated with BMI and children's eating styles (food responsiveness, emotional overeating, and desire to drink). Finally, overweight children classified more frequently non-food odorants as members of the food category during the pre-prandial state than during the post-prandial state, suggesting a possible influence of affective/motivational bias on odor categorization. Our findings suggest that orofacial responsiveness may be relevant to assess the sensitivity to energy-dense food *reward cues* in overweight children and for signaling, as an index of anticipatory liking, a potential risk for the development of overweight/obesity.

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Introduction

The development of overweight/obesity is promoted by the prevalence of 'obesogenic' environments in Western societies characterized by the availability of palatable energy-dense food, and increasingly *sedentary* lifestyles. It is therefore not surprising that childhood overweight/obesity has reached epidemic proportions worldwide over the last decades, and although France remains in a relatively favorable position, recent epidemiological surveys in 6-to-15 year-old children report rates attaining 18% in socio-

economically disadvantaged groups (Péneau et al., 2009; Pitrou, Shojaei, Wazana, Gilbert, & Kovess-Masféty, 2010).

Current theoretical frameworks recognize the key role of brain reward systems in appetite control and the regulation of body weight, and argue that reward-related behavior comprises two major components mediated by partially separable neural substrates (Berridge, 2009; Berthoud, Lenard, & Shin, 2011; Finlayson, King, & Blundell, 2007; Kenny, 2011; Rolls, 2011). One of these components reflects an affective/hedonic process that generates 'liking', viz., anticipated pleasure or pleasure derived from orosensory stimulations of eating a food. The other component reflects a motivational or incentive salience process that generates 'wanting', viz., the motivation to engage in eating a food (Berridge, 1996; Berridge, Ho, Richard, & DiFeliceantonio, 2010). Although the potential relevance of this dual process model of reward has been recently highlighted for a better understanding of overeating, it remains to better document how food liking and wanting interact, whether they can be disentangled in humans, and whether they constitute an independent risk factor for over-consumption and overweight/obesity (Berridge, 2009; Berridge et al., 2010; Finlayson et al., 2007; Havermans, 2011; Mela, 2006; Peciña & Smith, 2010). On

[☆] This work was conducted in four primary schools (St. Joseph, Trinité, Maladière, and Côteaux Suzon) of Dijon city, France. We acknowledge the parents and children, the heads and staffs of the schools and of the school canteens whom enthusiastic assistance made this research possible. This research was supported by a grant from the Regional Council of Burgundy (grant PARI). We acknowledge the companies Mane Fils (Bar sur Loup, France) and Asquali (Montaigut-Lauragais, France) that graciously provided the odorants. We are grateful to Professor J. Wardle for providing us the French version of the Children's Eating Behavior Questionnaire.

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the one hand, it has been suggested that the hedonics of eating can influence food intake and contribute to overeating and weight gain, and that a number of obese people might have a disposition to perceive foods as being more pleasant than their lean counterparts (Lowe & Levine, 2005; Yeomans, Blundell, & Leshem, 2004). This view is supported by evidence showing that: (i) adiposity and pleasantness ratings were positively related for fatty or sweet foods in both children and adults (de Graaf, 2008; Fisher & Birch, 1995; Le Noury, Lawton, & Blundell, 2002; Ricketts, 1997); (ii) obese people who binge eat had both higher scores of hedonic eating and an over-representation of the G allele of the mu-opioid receptor A118 G (Davis et al., 2009), suggesting higher sensitivity to the hedonic properties of foods possibly mediated by endogenous opioid neurotransmission in a subtype of obese people; (iii) the administration of opioid antagonists in obese binge-eaters reduced taste preferences and intake for sweet high-fat foods (Drewnowski, Krahn, Demitrack, Nairn, & Gosnell, 1992). On the other hand, it has been argued that reactivity to food cues in overweight/obese humans reflects increased motivation for food consumption, but not changes in pleasure of eating (Mela, 2006). Indeed, adiposity was not associated with subjective liking or preference for energy-dense foods in both children and adults (Drewnowski, Kurth, & Rahaim, 1991; Fieldstone, Zipf, Schwartz, & Berntson, 1997; Hill, Wardle, & Cooke, 2009), and only normal-weight women (as compared to overweight women) showed a decline in wanting, but not in liking, after confrontation with highly palatable food (Ouweland & de Ridder, 2008). Importantly, when wanting and liking were experimentally dissociated using progressive schedules of reinforcement as an objective measure of motivation to eat, overweight children and overweight/obese adults found energy-dense foods more reinforcing and consumed more energy than did their leaner counterparts, whereas self-reported food liking did not differentiate both weight groups (Giesen, Havermans, Douven, Tekelenburg, & Jansen, 2010; Saelens & Epstein, 1996; Temple, Legierski, Giacomelli, Salvy, & Epstein, 2008).

While previous studies suggest that food wanting is a key reward component able to clearly differentiate obese/overweight from normal-weight participants (but see Havermans (2011), for a critical review of human studies), the issue of whether liking may be a risk factor of overconsumption and overweight/obesity is somewhat controversial (Finlayson et al., 2007; Hill et al., 2009; Mela, 2006). Discrepancies in the literature concerning the functional status of hedonic processes in overeating/overweight might arise in part from the choice of subjective reports in most previous investigations. Since subjective reports are prone to social desirability effects, and reflect conscious introspection that may omit subtle, implicit changes in hedonic processes (e.g., Berridge & Kringsbach, 2008; Havermans, 2011; Soussignan, Schaal, Rigaud, Royet, & Jiang, 2011), it may be relevant to assess whether objective liking reactions to food cues would discriminate children according to their weight status. Observational techniques provide objective measures, with orofacial actions (e.g., lip licking, tongue protrusion) to tastants or odorants having been used as markers of implicit affective processing in animals and humans (e.g., Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003; Schaal, Marlier, & Soussignan, 2000; Steiner, Glaser, Hawilo, & Berridge, 2001).

The first aim of this study was to investigate whether distinct measures of liking (i.e., orofacial reactivity, self-rated pleasantness, and food preference) and a subjective measure of wanting differentiate overweight from normal-weight children while they were exposed to the *sight and smell* of high and low-energy density food stimuli and to non-food stimuli during pre- and post-prandial states. A cue-exposure approach was used because it may predict food intake and elicit anticipatory food responses (e.g., physiological and behavioral reactivity) (Jansen, 1998; Jansen et al., 2003). We hypothesized that orofacial reactivity, as an objective measure

of liking, should be more discriminative than subjective reports, with overweight children being more facially reactive to energy dense food cues than normal-weight children. If liking contributes to overeating, it is also expected that orofacial reactivity to food cues should be higher in overweight than normal-weight children in both hungry and satiated states because eating in the absence of hunger has been associated with body mass index (BMI) and adiposity (Fisher & Birch, 2002; Hill et al., 2008). A second purpose of this study was to examine whether sensory measures of food hedonics were related to children's eating behavior and appetitive traits as reported by the parents. The Children's Eating Behavior Questionnaire (CEBQ, Wardle, Guthrie, Sanderson, & Rapoport, 2001) was used as a reliable and valid parent-report instrument to assess 'obesogenic' eating behavior in children. Previous studies in different countries (England, Portugal, the Netherlands) have revealed that appetitive dimensions (e.g., food-cue responsiveness, satiety responsiveness) discriminated participants as a function of adiposity/BMI (Carnell & Wardle, 2008; Sleddens, Kremers, & Thijs, 2008; Viana, Sinde, & Saxton, 2008). Similar trends may as well arise in a French population of children. We also hypothesized positive relationships between BMI, orofacial reactivity to sensory cues, and food approach behavior (food responsiveness, enjoyment of food, emotional overeating, and desire to drink).

Method

Participants

First to five graders were recruited through four primary schools of Dijon (Burgundy, France). Parents were sent a letter describing the research and inviting them to take part, and to let their children take part, in the study. Eighty seven percent of them ($n = 325$) gave consent for their child to participate. From this sample, we selected the children taking their lunch at the school canteen during at least two consecutive days per week ($n = 150$). Twenty two of them were categorized as overweight, based on a standard definition using pooled international cutoff points for BMI (kg/m^2) adjusted for age and sex (Cole, Bellizzi, Flegal, & Dietz, 2000). The cutoff values for overweight are based on percentiles passing through BMI of $25 \text{ kg}/\text{m}^2$ at age 18 years; with cutoff points for overweight children (from 6.5 to 11 years) ranging between 17.71–20.55 in boys and 17.53–20.74 in girls. Two children were dropped because their diet excluded some foods that were used in the present study (e.g., delicatessen). Thus, a group of 20 children (9 girls) was constituted aged on average 8.5 ± 1.31 ($M \pm SD$) years (range: 6.41–10.75 years) and with a BMI of $20.93 \pm 1.62 \text{ kg}/\text{m}^2$ (range: 18.35–23.57 kg/m^2). To control for the influence of familiarity in food preference (Birch, 1999), we calculated child's frequency of consumption for the food items used in the present study by collecting data from parents' reports (see parent questionnaires). The food frequency of consumption was 3.26 ± 0.53 in overweight children. Normal-weight children were randomly selected from the initial sample ($n = 128$) with the constraint to be matched with the overweight children by age, gender and food familiarity index. The participants (9 girls and 11 boys) were 8.48 ± 1.37 years of age (range: 6.17–10.83 years), had a BMI of $15.54 \pm 1.20 \text{ kg}/\text{m}^2$ (range: 13.82–18.45 kg/m^2) and a food familiarity index of 3.30 ± 0.32 . The study was approved by the bioethics committee of the *National Centre for Scientific Research*, and all parents signed an informed consent to participate and let their child participate.

Stimuli

Pictures

The visual stimuli were composed of 4 pictures representing high-energy density foods (HiEF: a chopped steak in a plate, a slice

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