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Research report

Children's reward responses to picture- and odor-cued food stimuli. A developmental analysis between 6 and 11 years ☆

Tao Jiang [a,*], Benoist Schaal [b], Véronique Boulanger [b], Fayez Kontar [c], Robert Soussignan [b,*]

[a] Centre de Recherche en Neurosciences de Lyon, UMR 5292 CNRS-INSERM, Université de Lyon 1, Lyon, France
[b] Centre des Sciences du Goût et de l'Alimentation, UMR 6265 CNRS, Université de Bourgogne-INRA, Dijon, France
[c] University of Damascus, Faculty of Education II, Sweida, Syria

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ABSTRACT

The reward system is largely involved in the control of food intake. Whether components of this system (i.e., wanting and liking) change during development remains understudied, as well as how proximate factors (sensory cues, motivational state) modulate reward reactivity across development. We examined the developmental pattern of wanting and liking for sensorily-cued food stimuli in 6–11 year old children as a function of the child's motivational state (hunger/satiety), gender, and the nature of foods. School children were exposed before or after their lunch on alternative days to visual and odor stimuli representing different categories of familiar foods. Their task was to rate wanting and liking of pictures and odorants of pizza, meat, vegetables, fruits, and chocolate. The following results were found: (1) While liking appeared to be stable from age 6 to 11, more particularly for visually-cued foods, wanting decreased, as well as did subjective hunger perception; (2) there were smaller or absent state-effects in 7-to-9-year-olds; (3) reward ratings were higher in boys than in girls; (4) reward ratings of vegetables were the lowest at all ages. These results suggest that wanting, but not liking, is developmentally variable over childhood, and that this variation depends on age, gender, motivational state (hunger/satiety), the nature of the food and the modality of the sensory cue representing it. Such developmental changes are discussed in relation to biological (adiposity rebound) and cognitive (dietary restraint) factors influencing the motivation to eat during middle (6–7 years) and late (9–11 years) childhood.

Introduction

In Western and westernizing societies, the availability of foods that are consistently improving in palatability exposes people to an increasing abundance of alluring sensory cues that play an important role in the psychobiological cycle of food-related arousal, intake, satiation, and then craving for it again (Birch, 1999; Neary & Batterham, 2010; Smeets, Erkner, & De Graaf, 2010; Sorensen, Moller, Flint, Martens, & Raben, 2003). In this context, it is widely accepted that human eating behavior is not only driven by nutritional and caloric necessities and by health- and wellbeing-related cognitions, but it is also a matter of sensory cues encoded as pleasurable and rewarding (Lowe & Butryn, 2007; Mela, 2006; Yeomans, Blundell, & Leshem, 2004). Reactivity to such reward cues from foods is indeed a good predictor of intake (Bobroff & Kissileff, 1986; Rolls, Van Duijvenvoorde, & Rolls, 1984; Zandstra, De Graaf, Mela, & Van Staveren, 2000). Sensitivity to reward cues is also a recognized risk factor for overeating and for the engagement into developmental trajectories of overweight and obesity (Birch, 1998; Blass, 2008; Finlayson, King, & Blundell, 2007; Jansen et al., 2003; Mela, 2006; Soussignan, Schaal, Boulanger, Gaillet, & Jiang, 2012).

Thus, a better understanding on whether and how reactivity to food-related reward cues changes throughout childhood might shed additional light on the formative processes of food-related cognitions and emotions, and of eating habits. Although reactivity to sensory cues from food has been investigated in particular age-groups of participants, including either infants, children or adults (e.g., Birch & Fisher, 1998; Davis et al., 2009; Mennella & Beauchamp, 2002; Soussignan, Schaal, & Marlier, 1999; Soussignan, Schaal, Rigaud, Royet, & Jiang, 2011), ontogenetic changes of reward processing have been rarely examined in children following a developmental perspective. Such a perspective is needed to track whether infants or children are more reactive to some food cues

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* Corresponding authors.
E-mail addresses: tao.jiang@u-bourgogne.fr (T. Jiang), robert.soussignan@u-bourgogne.fr (R. Soussignan).

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during some periods of development and whether changes of sensitivity to reward cues at given ages may predict future food intake or attitudes toward eating.

Forerunning studies focused on age-related changes in food likes or dislikes relied prevalently on questionnaires completed by parents or children (e.g., Cooke & Wardle, 2005; Nicklaus, Boggio, Chabanet, & Issanchou, 2004; Perez-Rodrigo, Ribas, Serra-Majem, & Aranceta, 2003; Skinner, Carruth, Bounds, & Ziegler, 2002; Ton Nu, MacLeod, & Barthelemy, 1996), but more rarely on the developmental course of objective food-cue reactivity (e.g., Laing & Clark, 1983) or actual ingestive behavior of children (e.g., Rollins, Loken, & Birch, 2010). Collectively, these studies brought evidence for both stable and variable likes and dislikes for foods during childhood. Some findings reported relatively stable food preferences between 2 and 8 years of age (Nicklaus et al., 2004; Perez-Rodrigo et al., 2003; Rollins et al., 2010; Skinner et al., 2002), with changes, if any, occurring during puberty, especially in terms of increasing preference for vegetables (Nicklaus et al., 2004; Ton Nu et al., 1996). Other findings indicated a decrease in the number of liked foods and a stability of disliked foods from 4 to 16 years (Cooke & Wardle, 2005), or a tendency for initially disliked foods to become more liked from age 5 to 11 (Rollins et al., 2010), or even an increase of disliked foods from the age of 2 to 8 (Skinner et al., 2002). Thus, extant studies of age-related changes in food preferences do not provide a wholly coherent picture, probably because of considerable between-studies differences in terms of age and gender composition of groups, cultural background, design (cross-sectional *vs.* longitudinal), target respondent (child *vs.* mother), number, nature, and presentation of test food items, response format (categorical, ordinal, continuous), and possibly uncontrolled factors influencing food pleasantness [i.e., motivational state, body-mass index (BMI), earlier experience (breast-feeding)]. These studies being mainly descriptive in nature and based on questionnaires, they dealt only tangentially with proximate factors influencing age-related changes in food preferences along childhood, such as sensory cues, motivational state and nature of reward processes. The present study aimed to further contribute to the issue of proximate mechanisms underlying childhood variations in food preferences by examining stability and change in reactivity to reward elicited by selected food stimuli.

Evidence from neurobiological (Berridge, 2009; Davis et al., 2009), neuroimaging (Born et al., 2011) and behavioral studies (Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003; Finlayson et al., 2007) supports that food reward can be decomposed in at least a motivational component named "wanting" (*viz.*, motivation to eat a food, desire) and an affective component, named "liking" (including both the sensory pleasure of food intake and its remembered pleasantness) (Berridge & Robinson, 2003). To our knowledge, only one recent study (Olsen, Ritz, Hartvig, & Møller, 2011) has simultaneously investigated wanting and liking responses to sensory attributes of foods in comparing 10-year-old children and adults. Wanting and liking were assessed on a visual-analogue scale for a target food (sweet pear-banana yoghurt), and for real test foods conveying sweet-fruity, salty-starchy, sour-fruity, bitter-citrus, fatty, and spicy-fatty flavors evaluated (after an actual taste of them) before/after the target food was eaten to satiation. While some aspects of reward responsiveness were similar across age groups (i.e., post-meal drop in wanting for target food larger than in liking), other aspects differentiated them. Adults decreased their liking and desire for the test foods (sweet, fruity) that resembled the target food, while children did not. In contrast, children evinced post-meal increased liking for spicy items and wanting for salty items, while adults did not. Thus, Olsen et al. revealed child–adult differences in wanting and liking responses to foodstuffs bearing distinct appearances and flavors from a satiating food. This finding of age-related shift in the motivational underpinnings of eating behavior stimulates a developmental analysis of reward responsiveness during childhood. Being focused on a child–adult comparison, Olsen et al.'s study was not developmental in terms of characterizing phenomenological and mechanistic processes underlying food appreciation and appetence along childhood. Human childhood, *viz.* the period between weaning and sexual maturity, is indeed highly heterogeneous regarding, among other biological and psychobiological processes, growth of different body tissues, energy allocation, patterns of fat deposition, and metabolic efficiency (e.g., Bogin, 1997; Konner, 2010; Rolland-Cachera et al., 1987). It is thus expectable that sensory, perceptual and motivational processes controlling ingestive behavior are, at least in part, patterned by these changing psychobiological constraints.

A critical factor that has often been overlooked in previous studies on age-related variations in food preferences (except in Olsen et al., 2011) is the influence of the participant's actual motivational state on self-reported reward assessment. The rating of food pleasantness varies indeed as a function of hunger/satiety states (*viz.*, alimentary alliesthesia: Cabanac, 1971). Alimentary alliesthesia has been observed for odor, taste and sight of foods in adults (Cabanac & Duclaux, 1973; Stoeckel, Cox, Cook, & Weller, 2007), but also in infants (Soussignan et al., 1999). In adults, the magnitude of this variation depends on both the type of food and the sensory mode of its perception (Jiang et al., 2008).

Motivational responses to food are also quite deeply influenced by gender. Gender differences in wanting/liking responses to either real foods or food stimuli have been confirmed in adults (Cornier, Salzberg, Endly, Bessesen, & Tregellas, 2010; Killgore & Yurgelun-Todd, 2010; Nakamura, Shimai, Kikuchi, & Tanaka, 2001) and adolescents (Bere, Brug, & Klepp, 2008; Brug, Tak, te Velde, Bere, & de Bourdeaudhuij, 2008; Le Bigot Macaux, 2001). But less conclusive results derive from research in infants and prepubertal children. Among the studies on food liking in children, some have not regarded gender as a variable (Olsen et al., 2011), while others found either no difference (Perez-Rodrigo et al., 2003) or early variability consistent with that of older participants (Cooke & Wardle, 2005; Nicklaus et al., 2004). However, the onset period of the gender-based differences in both liking and wanting for food remains to be clarified. As the growth-related metabolic constraints outlined above are gender differentiated (e.g., Bogin, 1997), it is expectable that gender discriminates motivational processes in ingestion. The present study is thus also designed to assess whether and when during middle and late childhood gender differences emerge in the wanting and liking of food-related stimuli.

Finally, available studies on aspects of children's food reward assessment (mostly liking) used either large nominal listings of food items in the form of questionnaires, often completed by parents (Cooke & Wardle, 2005; Nicklaus et al., 2004; Perez-Rodrigo et al., 2003; Skinner et al., 2002; Ton Nu, MacLeod, & Barthelemy, 1996) or a restricted number of real foods (Olsen et al., 2011; Rollins et al., 2010). Number of studies have instead opted to present participants with sensory cues – pictures, odors, flavors – derived from foodstuffs as proxies to real foodstuffs, and were able to reliably predict food preferences and intake (e.g., Beauchamp & Mennella, 2009; Born et al., 2011; Cornier, Von Kaenel, Bessesen, & Tregellas, 2007; Jansen, 1998; Jansen et al., 2003; Soussignan et al., 2012; Staiger, Daweb, & McCarthy, 2000). This approach relies on the fact that before a food is eaten, vision and olfaction prevail in the decision to select it and ingest it (Beauchamp & Mennella, 2011; Fedoroff, Polivy, & Herman, 2003; Ferriday & Brunstrom, 2008; Nederkoorn & Jansen, 2002; Ohla, Toepel, le Coutre, & Hudry, 2012). Although offering sensory cues (*viz.*, pictures, odors) extracted from real foods certainly is a reduction in ecological validity, this approach has experimental advantages, such as the avoidance of semantic biases that are inherent to lists of food