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Pre- and postprandial variation in implicit attention to food images reflects appetite and sensory-specific satiety

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ABSTRACT

Implicit attentional processes are biased toward food-related stimuli, with the extent of that bias reflecting relative motivation to eat. These interactions have typically been investigated by comparisons between fasted and sated individuals. In this study, temporal changes in implicit attention to food were assessed in relation to natural, spontaneous changes in appetite occurring before and after an anticipated midday meal. Non-fasted adults performed an emotional blink of attention (EBA) task at intervals, before and after consuming preferred, pre-selected sandwiches to satiety. Participants were required to detect targets within a rapid visual stream, presented after task-irrelevant food (preferred or non-preferred sandwiches, or desserts) or non-food distractor images. All categories of food distractor preferentially captured attention even when appetite levels were low, but became more distracting as appetite increased preprandially, reducing task accuracy maximally as hunger peaked before lunch. Postprandially, attentional capture was markedly reduced for images of the specific sandwich type consumed and, to a lesser extent, for images of other sandwich types that had not been eaten. Attentional capture by images of desserts was unaffected by satiation. These findings support an important role of selective visual attention in the guidance of motivated behaviour. Naturalistic, meal-related changes in appetite are accompanied by changes in implicit attention to visual food stimuli that are easily detected using the EBA paradigm. Preprandial enhancement of attention capture by food cues likely reflects increases in the incentive motivational value of all food stimuli, perhaps providing an implicit index of wanting. Postprandial EBA responses confirm that satiation on a particular food results in relative inattention to that food, supporting an important attentional component in the operation of sensory-specific satiety.

1. Introduction

A broad range of studies have demonstrated that we possess an innate attentional bias for food stimuli, indicative of a preferential allocation of cognitive resources to the detection of nutritive items within our environment. Moreover, as might be expected, the ability of food to capture our attention is enhanced when our motivation to eat is increased. Thus, while a preferential attentional bias toward food may be evident even in the absence of need (e.g., Garcia-Burgos, Lao, Munsch, & Caldara, 2017; Nummenmaa, Hietanen, Calvo, & Hyönä, 2011), experiments using a variety of spatial and temporal attention tasks have found that hunger induced by fasting increases attentional bias to food-related stimuli in Stroop, visual probe, eye-tracking and attentional blink paradigms (e.g., Castellanos et al., 2009; Channon & Hayward, 1990; Lavy & van den Hout, 1993; Loeber, Grosshans, Herpertz, Kiefer, & Herpertz, 2013; Mogg, Bradley, Hyare, & Lee, 1998; Nijs Muris, Euser, & Franken, 2010; Piech, Pastorino, & Zald, 2010; Placanica, Faunce, & Soames Job, 2002).

An important consideration when considering how attention to food might vary in relation to meal taking is that satiety is not an absolute phenomenon. The termination of eating of a particular food might be associated with subjective reports of a reduced desire to eat or feelings of fullness, but a recrudescence of the motivation to eat and further consumption are easily induced by the presentation of different, tempting foods. This phenomenon, which relates directly to the impact of the incentive salience and hedonic evaluation of food, is known as sensory-specific satiety (Havermans, Janssen,

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Giesen, Roefs, & Jansen, 2009; Rolls, Rolls, Rowe, & Sweeney, 1981). Sensory-, or food-specific satiety refers to the observation that the pleasantness of the sight and taste of a food that is eaten to satiety declines compared to other positively-evaluated foods that have not been consumed. Consequently, appetite may be prolonged and overconsumption stimulated by the availability of a variety of, particularly highly palatable, foods: a phenomenon that is apparent in buffet meal situations, and which underlies the division of meals into distinct courses that is found in many cuisines (Hetherington & Rolls, 1996; Remick, Polivy, & Pliner, 2009).

In relation to attentional bias to visual food stimuli, sensory-specific satiety might be predicted to be reflected in changes in the ability of different foods to capture our attention, dependent on their relative motivational (incentive) or emotional (hedonic) salience, and to be linked to the consumption of particular foods. To date, this possibility has been investigated in only a single study (di Pellegrino, Magarelli, & Mengarelli, 2011). Di Pellegrino and colleagues used a visual probe task to assess attention to pictures of two palatable test foods (crackers and cookies) that were initially rated as having equivalent levels of pleasantness. Attentional bias to the food stimuli was assessed in 6-h fasted participants, before and after they had eaten to satiety on one of the food types. Before eating, the two foods were able to capture attention to a similar degree. However, after satiation there was a marked attenuation of attentional bias to, and reduction in pleasantness ratings of, the food that had been consumed. Moreover, for the food that was eaten, the greater the reduction in its reported pleasantness, the greater was the reduction in attentional bias. Thus, the authors concluded that the transitory changes in the relative preference for different foods that characterize sensory-specific satiety are mirrored by adjustments to the allocation of visual attention – away from food that has been recently consumed and that is consequently hedonically devalued (di Pellegrino et al., 2011). For the omnivore, such a mechanism would favour the optimal exploitation of a range of available food resources and promote a varied diet, so avoiding potentially injurious overconsumption of a single food and maximizing the opportunity to meet the requirement for essential nutrients and energy (di Pellegrino et al., 2011; Kirkham, 2009; Rolls et al., 1981).

The above study also represents the only one in which attentional bias for food has been assessed directly in relation to the transition from hunger to satiety within the same individuals, immediately before and after eating: other studies have used different groups of participants to compare hungry or sated attentional responses; or, when the same individuals have been tested, fasted and fed conditions commonly did not occur in the same experimental session.

In the present study, we were concerned to extend the analysis of motivation-attention interrelationships beyond the simple comparison of fasted or fed states, and investigate the extent to which dynamic changes in attentional bias to food cues are linked, over time, to the rise and fall of eating motivation that naturally precede and follow food consumption at predictable mealtimes. Consequently, we monitored naturalistic temporal changes in these variables over several hours before and after an *ad libitum* lunch, in habitual lunch-eaters who attended the laboratory without any prior restriction on their food intake and who followed their normal breakfasting routine. In addition, we wished to further characterize any attentional correlates of sensory-specific satiety in light of the findings of di Pellegrino et al., 2011. Accordingly, we adopted an emotional blink of attention (EBA) task, in which the presentation of a task-irrelevant, motivationally or emotionally salient distractor image within a rapid serial visual presentation (RSVP) can induce an attentional blink that reduces one's ability to subsequently detect a specific target (Most, Chun, Widders, & Zald, 2005). The EBA paradigm is regarded as a powerful measure of stimulus-driven attention, assessing the capacity of salient stimuli to preferentially capture attentional resources (McHugo, Olatunji, & Zald, 2013). More specifically, we adapted the EBA technique of Piech et al. (2010) with which they successfully demonstrated that food distractor images more effectively induced an attentional blink in participants when they were fasted overnight, compared to when they were sated.

In the experiment described here, the EBA task was repeated at regular intervals both before and after an *ad libitum* sandwich lunch, in which participants consumed a pre-selected, preferred sandwich type to satiety. Within successive RSVP streams, distractor images consisted of photographs of either the specific type of sandwich that would be eaten at lunchtime, or sandwiches with different fillings that would not be consumed, or pictures of desserts. These two distinct categories were chosen to reflect foods that are likely to be eaten at lunch by our participant population and, being discernibly either savoury or sweet, to reflect the usual course structure of meals and also facilitate detection of sensory-specific effects (Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010; Rolls, Van Duijvenvoorde, & Rolls, 1984).

Thus, we were able to assess the temporal variation in attention to food in general, against changing levels of pre- and postprandial eating motivation, and also selective adjustments in the relative attentional bias to the different categories of consumed or non-consumed foods that might reflect sensory-specific satiety. We anticipated that as motivation to eat increased as lunchtime approached, food images would become increasingly more distracting, reflecting their greater motivational salience, and lead to lower accuracy in the EBA task. We were also interested in respective temporal changes in attentional capture by the different food types, reflecting relative preference for different foods and, particularly, the foods chosen by the participants for their lunch. Meal consumption and satiation were expected to result in lessened attentional capture by food images, resulting in higher postprandial task accuracy. We also assessed whether sensory-specific satiety might be evident in a greater postprandial reduction in attentional bias, and hence more improved EBA accuracy, on trials when distractors depicted the actual food that had been consumed, compared to images of distinctly different foods (desserts) or other, uneaten sandwich types.

2. Method

2.1. Participants

Twenty-nine adults (12 males, 17 females), aged between 18 and 40 (mean ± SD = 23.4 ± 3.7 years), with a mean BMI of 24.3 ± 4.3, were recruited from the University of Liverpool campus and the surrounding community, using advertisements and opportunity sampling methods. Participants were required to have normal or corrected-to-normal vision, to be non-smokers, non-dieters and habitual lunch eaters. Exclusion criteria included the recent or current use of any medication that might affect appetite or attention, or any food allergy or intolerance. Volunteers were informed that the study was investigating how people's attention to motivationally significant stimuli change over time in relation to fluctuating motivational state, but no specific reference was made to the central focus on changes in attention to food in relation to the motivation to eat. Participants were financially reimbursed for their involvement in the experiment. Ethical approval for the study was obtained from the University of Liverpool's Institute of Psychology, Health and Society Ethics Committee.

2.2. Emotional blink of attention task

The study adapted the emotional blink of attention (EBA) paradigm previously reported by Piech et al. (2010), using a