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Effects of eating rate on satiety: A role for episodic memory?

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HIGHLIGHTS

- Eating lunch at a slower rate promotes greater satiation and satiety.
- Participants remember eating a larger meal if they eat it slowly.
- Eating lunch at a slower rate does not affect subsequent snack-food intake.
- Effects of eating rate on satiety might not be mediated by episodic memory.

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ABSTRACT

Eating slowly is associated with a lower body mass index. However, the underlying mechanism is poorly understood. Here, our objective was to determine whether eating a meal at a slow rate improves episodic memory for the meal and promotes satiety. Participants ($N = 40$) consumed a 400 ml portion of tomato soup at either a fast (1.97 ml/s) or a slow (0.50 ml/s) rate. Appetite ratings were elicited at baseline and at the end of the meal (satiation). Satiety was assessed using; i) an *ad libitum* biscuit 'taste test' (3 h after the meal) and ii) appetite ratings (collected 2 h after the meal and after the *ad libitum* snack). Finally, to evaluate episodic memory for the meal, participants self-served the volume of soup that they believed they had consumed earlier (portion size memory) and completed a rating of memory 'vividness'. Participants who consumed the soup slowly reported a greater increase in fullness, both at the end of the meal and during the inter-meal interval. However, we found little effect of eating rate on subsequent *ad libitum* snack intake. Importantly, after 3 h, participants who ate the soup slowly remembered eating a larger portion. These findings show that eating slowly promotes self-reported satiation and satiety. For the first time, they also suggest that eating rate influences portion size memory. However, eating slowly did not affect ratings of memory vividness and we found little evidence for a relationship between episodic memory and satiety. Therefore, we are unable to conclude that episodic memory mediates effects of eating rate on satiety.

1. Introduction

People consume smaller meals if they eat at a slower pace [1–3]. By contrast, foods that are eaten quickly tend to be consumed in larger portions [4,5] and have lower expected satiation [6,7]. For a recent systematic review and meta-analysis see Robinson et al. [2]. These acute effects are consistent with evidence that faster eating is associated with a higher body mass index (BMI) [8–12] and that clinically significant (sustained over 12 months) reductions in body weight can be achieved by training obese adolescents to eat slower [13]. Nevertheless, and despite its importance, the underlying causal mechanism that supports a relationship between eating rate and food intake remains poorly understood. In particular, it is unclear how and whether [14] eating rate might influence satiety (the absence of hunger) between meals.

To date, researchers have focused on potential physiological mechanisms. Greater oral processing of a food has been suggested to; i) elicit a stronger cephalic phase response [1], ii) stimulate the release of 'satiety hormones' [15,16], iii) delay gastric emptying [17], and iv) increase lipid bioaccessibility [18]. However, findings relating speed of eating to the release of specific satiety hormones [2,14] and gastric emptying rate [19] have been inconsistent. Here, we test an alternative (but not mutually exclusive) cognitive explanation. Specifically, we test the hypothesis that eating slowly promotes 'attentive eating', which reinforces the encoding of episodic memory for a meal.

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There is accumulating evidence that attentive eating and episodic memory play a central role in the control of energy intake [20,21]. Specifically, it appears that memory (implicit or explicit) of a recent eating episode influences portion selection and energy intake at a subsequent meal. For a recent systematic review and meta-analysis see Robinson et al. [21]. Briefly, it has been noted that amnesic patients demonstrate hyperphagia — they have no memory for a recent meal and experience little change in hunger and fullness shortly after it has been consumed [22,23]. In neurologically intact participants, there are also converging findings that support an independent role for episodic memory as a determinant of satiety. First, Higgs and colleagues [20,24–26] have demonstrated that food intake is reduced if people are asked to recall details of a recent meal. Second, distracting people while they eat has been found to reduce fullness at the end of a meal [27] and to increase food intake at a subsequent meal [28,29]. Third, attending to the sensory characteristics of a meal reduces intake at a subsequent meal [30,31]. Finally, in one study the independent roles of episodic memory and gastric feedback were dissociated by manipulating the physical amount of soup that participants consumed relative to the amount they observed [32]. Post-meal hunger was predicted by the remembered rather than the actual portion size, again implicating an important role for episodic memory.

To the authors' knowledge, only one study has explored a causal relationship between oral processing and episodic memory. Specifically, Higgs and Jones [33] showed that increased chewing reduces food intake at a subsequent meal. However, this manipulation had little effect on ratings of memory 'vividness'. A potential concern is that measures of memory vividness might be dissociable from measures of memory accuracy [34]. In particular, the role of memory for portion size has been implicated [32] and discussed elsewhere [35,36].

The present study had two objectives. First, we were interested to determine whether eating rate influences fullness at the end of a standard meal and the extent to which this effect is preserved in the inter-meal interval. Participants consumed a fixed portion of soup for lunch. Eating rate was fixed at either a fast or a slow pace. We hypothesised that participants who eat slowly will report greater satiation and greater satiety, and will consume less food at a subsequent snack. Second, we explored evidence that the underlying process is mediated by an effect of eating rate on episodic memory for the lunch. Following a related study [33], we quantified episodic memory using ratings of memory vividness. We also incorporated a novel assessment of memory for portion size.

2. Methodology

2.1. Participants

Forty participants (20 women and 20 men) were recruited from the staff and student populations of the University of Bristol (United Kingdom) and took part in the study. To reduce demand awareness, participants were told that the purpose of the study was to explore 'The effects of mood on appetite ratings, taste perception and cognitive performance.' We excluded participants if they were; i) vegetarian or vegan, ii) not fluent in English, iii) trying to lose weight, iv) taking any medication that might influence appetite or metabolism (with the exception of oral contraceptive pills), or v) allergic or intolerant to any foods. Our sample had a mean age of 23.6 years ($S.D. = 6.0$; range = 18–51) and a mean BMI of 22.8 kg/m^2 ($S.D. = 3.4$; range = 17.3–32.5). Participants were allocated to either a fast or a slow eating-rate condition ($n = 20$ in each). In remuneration for their assistance, all were offered £15 (Sterling) upon completion of the study. The protocol for the study was approved by the University of Bristol Faculty of Science Human Research Ethics Committee.

2.2. Eating rate manipulation

Participants consumed a warm tomato soup for lunch (Sainsbury's Supermarkets Ltd, London, U.K.; 59 kcal per 100 ml). Soup was chosen as a test meal because it is at least as satiating as solid foods [37–39]. To manipulate oral processing, we used a technique that has been employed previously to investigate the effects of sip size and eating rate on *ad libitum* intake [40,41]. Specifically, the soup was consumed through a temperature-insulated food-grade tube. Participants sat at a table covered by a table cloth. A tall screen was positioned to the left of the participant. The tubing connected to a reservoir of soup (600 ml) via a peristaltic pump (Watson-Marlow, type 323 Du). See Fig. 1 for a depiction of the experimental set-up. Throughout the experiment, the volunteers were unable to see either the pump or the reservoir. Participants were informed that they would be consuming their lunch through a tube because "…people differ in their eating rate, which has been shown to affect people's appetite" and that we were using the pump "…so that everyone eats at the same rate and we can rule out differences that might affect the results." Each participant consumed 400 ml of soup and the time taken to consume the meal was recorded by the experimenter. To ensure that any effects of eating rate could not be attributed to differences in water intake during the meal [42], participants were given a fixed amount of water with their meal (250 ml) and water intake (g) was recorded.

In the fast eating rate condition, the pump alternated between 2 s of soup delivery (average bite size of 11.8 ml) and 4 s of inactivity. In the slow eating rate condition, 1 s of activity (average bite size of 5.4 ml) was followed by 10 s of inactivity. Note that every time the pump was activated and deactivated it accelerated and decelerated. Across conditions the pump was activated more often in the slow condition, which accounts for the relative difference in flow rate (ml/s).

2.3. Taste test

Three hours after lunch, participants took part in a bogus taste test using two different types of biscuits. The procedure for the taste test was identical for all participants. They were presented with two separate 1000 ml clear glass bowls containing 'custard cream' biscuits (1000 kcal; 203.3 g) and chocolate chip cookies (1000 kcal; 202.8 g). Biscuits were broken to prevent the participants from counting the number that they had eaten. All foods were supplied by Sainsbury's Supermarkets Limited, Holborn, London. For each type of biscuit, participants were asked to rate five attributes; pleasantness, flavour intensity, sweetness, saltiness, and sourness. Ratings were anchored by 'not at all' on the left and 'extremely' on the right. Pleasantness ratings were included to establish whether a difference in intake might otherwise be attributed to a differential liking for the biscuits across conditions. Participants were told that any remaining biscuits would be thrown away at the end of the session and that they should feel free to eat as many as they would like. They were not permitted to remove biscuits from the lab at the end of the session. After 10 min, the experimenter returned to the room, removed the biscuits, and the amount consumed (g) was recorded. The amount eaten of each type of biscuit was converted to calories and these values were summed. Participants were also provided with a 250 ml glass of water and water intake (g) was recorded. No other water was made available.

2.4. Measures

2.4.1. Appetite and thirst

Participants rated their hunger (Heading: "I feel hungry"; anchor points: "Not at all" and "Extremely") and fullness (Heading: "My stomach feels full"; anchor points: "Not at all" and "Extremely") on a computerised 100-mm visual-analogue scale (VAS). From each pair of values, a composite 'fullness score' was calculated using the formula $((100 - \text{hunger}) + \text{fullness}) / 2$). Participants also rated their thirst