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Mindful Eating and Food Intake: Effects and Mechanisms of Action

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Abstract

A key component of mindful eating is paying attention to the sensory properties of one's food as one eats ('sensory eating'). Some studies have found this reduces subsequent food intake whilst others have failed to replicate these effects. We report four laboratory studies that (a) examine effects of sensory eating on subsequent intake, and (b) explore potential mechanisms of action. In each study, participants ate a small high calorie snack with or without sensory eating and, 5-15 minutes later, were given larger snack portions from which they could eat freely. Sensory eating reduced intake of the second snack and could not be explained by increased sensory-specific satiety or priming of health-related goals. However, this effect disappeared when we controlled eating rate for the first snack. Given evidence that slower eating increases satiation and reduces intake, we conclude that sensory eating reduces intake by slowing eating rate. Exploratory analyses also revealed that (among non-dieters) effects of sensory eating were pronounced when participants reported higher hunger. Thus, for weight management, sensory eating may be most beneficial for those who are naturally fast eaters and/or in situations where people are inclined to eat more quickly, for example when hungry or in a hurry.

Keywords: mindfulness; sensory eating; epicurean eating; food intake; eating rate

Public significance statement: This research suggests that paying attention to the sensory properties of one's food whilst eating could help reduce intake. This seems to occur because it is associated with a slower rate of eating. As such, this strategy may be particularly effective among those who are naturally fast eaters or in situations where people are inclined to eat more quickly, for example, when hungry or in a hurry.

Mindful Eating and Food Intake: Effects and Mechanism of Action

Mindful eating is increasingly being promoted as a means of eating more healthily and managing one's weight. However, popular support for this approach goes beyond current evidence for effects. We also lack a full understanding of potential mechanisms of action which limits our ability to confidently incorporate mindful eating strategies into health promotion advice and intervention (Tapper, 2017; 2022).

Mindfulness is the practice of intentionally maintaining attention on one's present moment experience with an attitude of openness and acceptance (Kabat-Zinn, 2003). Mindful eating can be defined as the application of mindfulness to eating-related thoughts, emotions, bodily sensations and behaviors (Tapper, 2022). As such, the term 'mindful eating' refers to a varied set of practices that could engage diverse psychological and physiological mechanisms to influence behavior in a range of different ways. This variation makes it difficult to establish causal effects for specific practices and to pinpoint mechanisms of action. In this research we address this by taking a dismantling approach and examining just one mindful eating practice in isolation, paying attention to the sensory properties of food. Hereafter termed 'sensory eating', this practice is a key feature of mindful eating interventions and involves attending to the look, smell, taste and texture of one's food as one eats.

Sensory Eating is Not Just the Absence of Distractions

However, before examining the literature on sensory eating, it is important to first distinguish between this practice and eating in the absence of distractions. There is evidence that eating whilst engaged in another activity, such as watching television, reading, or socialising *increases* both concurrent and later intake. This is likely because it shifts attention away from eating which in turn impairs memory for food eaten and reduces food habituation as well as feelings of fullness and sensory-specific satiety (see sections below for further discussion of these mechanisms and a definition of sensory-specific satiety; Robinson, Aveyard et al., 2013; Ruddock, Brunstrom & Higgs, 2021; Brunstrom & Mitchell, 2006; Oldham-Cooper, Hardman, Nicoll, Rogers & Brunstrom, 2011; Rogers, Drumgoole, Quinlan & Thompson, 2021; Temple et al., 2007; Higgs, 2016; though see also Martins et al., 2022). It therefore follows that removing environmental distractions should reduce intake. Indeed, advice to eat without distractions is often paired with advice to mindfully attend to the sensory properties of one’s food. However, it is important not to confuse these two strategies. Whilst removing distractions might naturally lead one to pay more attention to one’s food, such attention could be primarily directed at the non-sensory aspects of the food, such as portion size or perceived healthiness. Alternatively, one could be preoccupied with something entirely different (such as a work deadline). Likewise, one could still intermittently pay attention to the sensory properties of one’s food, even when engaged in another activity, such watching television or conversing with friends. This distinction between eating without distractions versus sensory eating is important because, for many people, the former may be neither practical nor desirable (Seguias & Tapper, 2022).

Effects of Sensory Eating on Food Intake

To date, research examining the effects of sensory eating on intake has shown mixed results. In laboratory settings, three studies failed to show any effects of instructing participants to attend to the sensory properties of their food (relative to no instruction) on concurrent *ad libitum* meal consumption where those meals comprised pasta and sauce (Long et al., 2011, Simonson et al., 2020) and beef and potato casserole plus fruit sherbet (Bellisle & Dalix, 2001).

Other laboratory studies have examined the effects of this instruction on *subsequent* consumption of energy-dense foods. In these studies participants have typically been provided with a meal or snack to eat with instructions to attend to its sensory properties (versus no instructions). Either immediately after, or up to 3 hours later, they have then been provided with an additional energy-dense snack or meal (such as cookies, chocolate or pasta and sauce), which they have been able to eat *ad libitum*, in the absence of any further instructions, and usually under the guise of carrying out another task, such as a taste test. Some of these studies have found reduced consumption of this subsequent food among those who were asked to attend to the sensory properties of the first meal or snack (Allirot et al., 2018; Arch et al., 2016; Higgs & Donohoe, 2011; Mantzios et al., 2020; Robinson, Kersbergen et al., 2014; Seguias & Tapper, 2018). However, others have failed to find effects (Cavanagh et al., 2014; Whitelock et al., 2018; 2019).

A further two studies have looked at the effects of sensory eating on consumption outside the laboratory, over a half day period and over a period of 3 days (Tapper & Seguias, 2020; Seguias & Tapper, 2022). Both studies failed to find effects.

There are three possible reasons for these mixed findings. First, the field may be subject to publication bias; of the three studies that were pre-registered (Tapper & Seguias, 2020; Whitelock et al., 2018, 2019), none found significant effects. Second, it may be that participant adherence to instructions was simply too low in some studies to lead to significant effects. Indeed, few studies attempted to measure the extent to which the manipulation significantly increased participants' attention toward the sensory properties of their food. Of the five that did include a relevant measure, three found evidence for more mindful eating in the experimental condition (Arch et al., 2016; Mantzios et al., 2020; Tapper & Seguias, 2020) whilst two found no such evidence (Allirot et al., 2018, Simonson et al., 2020). Thus, in some studies, an absence of effects on food intake could be accounted for by manipulation failure. In other words, participants may simply have failed to attend to the sensory properties of their food. The third possible explanation for the mixed findings is that there are particular variables, as yet unidentified, that moderate effects. This is considered in the section that follows.

Toward Theoretical Understanding

One possible way of identifying potential moderators is via meta-analyses of empirical data. For example, sub-group analyses can examine the moderating effects of variables relating to participant or study features, such as gender, hunger or food type. Another approach is to extrapolate from theory. For example, if we know that mindful eating promotes healthy eating only because it reminds people of their health-related goals, it follows that it will have no effect on those who have no interest in healthy eating. However, the field of mindful eating (and, arguably, mindfulness more generally) currently lacks a well-articulated theory (Tapper, 2017; 2022). This limits our ability to know when specific mindful eating strategies are, and are not, likely to be effective. As such, developing a better understanding of the mechanisms underpinning effects should be a key priority, since this will help us build theoretical understanding. The sections that follow consider a range of possible explanations for effects of sensory eating on food intake. Two of these explanations (memory, conditioned associations) could apply to effects on subsequent consumption only, whilst the other four (sensory-specific satiety, sensory pleasure, health goals, slowed eating) could apply to both concurrent and subsequent consumption. However, given stronger evidence for effects on subsequent consumption (see above), this is the focus of the current research.

Enhanced Memory for Food Eaten

Higgs and Donohoe (2011) suggested that sensory eating enhances episodic memory for food eaten and that this information is then used to interpret physiological cues and inform subsequent decisions about how much to eat. Evidence for the role of memory in food intake comes from amnesic patients who eat multiple meals, and also from experimental studies that have shown reduced food intake amongst those who have been prompted to remember their previous meal (Rozin, Dow, Moscovitch, & Rajaram, 1998; Higgs, 2002; Higgs, Williamson, & Attwood, 2008, see also Higgs, 2016). However, whilst Higgs and Donohoe found that sensory eating led to participants reporting more vivid memories of that food (and eating less later in the day), subsequent studies have failed to replicate the effects on memory. Specifically, Robinson, Kersbergen and Higgs (2014) found that sensory eating reduced snack intake 2-3 hours later but did not influence memory vividness. Likewise, other studies have found no effects of sensory eating on memory vividness, interoceptive memory, memory for quantity of food consumed or memory for type of food consumed (Seguias & Tapper, 2018; Tapper & Seguias, 2020). Thus, although improved memory for eating may reduce later food intake, this does not appear to be the primary mechanism underlying the effects of sensory eating. As such, we do not explore memory in the current studies.

Weakening of Conditioned Associations

Another possibility is that sensory eating reduces subsequent motivation for food by weakening associations formed through classical conditioning. Food consumption can be viewed as an unconditioned stimulus that elicits unconditioned physiological responses, such as salivation, gastric activity and insulin release. However, through a process of classical conditioning, external cues associated with eating, such as the sight and smell of a food, can also elicit these responses, along with feelings of hunger and motivation to eat (Weingarten, 1985; Nederkoorn et al., 2000; Ferriday & Brunstrom, 2011). Research by Rescorla (1970) suggests that the simultaneous presentation of multiple conditioned stimuli can actually weaken the extent to which they subsequently elicit the unconditioned response. For example, Rescorla conditioned rats to associate both a tone and, separately, a light with an electric shock. He then paired both the tone and the light (combined) with the shock. In subsequent trials where just the light or the tone were presented, the rats demonstrated a reduced fear response. He suggested this was because, when presented in combination, the conditioned stimuli (the light and tone) overpredicted the strength or occurrence of the unconditioned stimulus (the shock), which weakened the association between the conditioned and unconditioned stimuli, which in turn reduced the unconditioned response (fear). This finding has been termed the overexpectation effect. Treanor (2011) outlines the success of mindfulness interventions in the treatment of anxiety disorders and proposes that mindfulness might facilitate extinction learning by increasing attentional capacity and awareness of multiple conditioned stimuli (thereby inducing overexpectation). Applying the same logic to food, there are a range of different external stimuli associated with food consumption (such as the sight and smell of food as well as its feel on fingers and lips). Sensory eating might increase attentional capacity and encourage an individual to actively attend to all these conditioned stimuli prior to consumption. In turn, this might overpredict the unconditioned stimulus and response (i.e. food consumption and its associated physiological responses). Thus, when these cues are subsequently encountered (and attended to in a reduced fashion), they may be less strongly associated with consumption and so elicit less desire to eat. If this were the case, we would expect sensory eating to lead to reduced food-cue reactivity and reduced motivation to eat. (See Treanor, 2011 for a more detailed explanation of how this process may account for the effects of mindfulness on anxiety reduction.)

Increased Sensory-Specific Satiety

Sensory-specific satiety refers to the fact that as we eat a particular food, its pleasantness declines relative to other foods not eaten. This phenomenon is thought to be underpinned by stimulus satiation and functions to promote dietary diversity. Effects last for up to 2 hours and tend to extend to foods with similar sensory properties (Hetherington, Rolls &

Burley, 1989; Hetherington & Havermans, 2013). For example, we might feel satiated on a savory main course but still have room for a sweet dessert. However, as noted above, research shows that distraction reduces sensory-specific satiety (Brunstrom & Mitchell, 2006; Rogers et al., 2021). As such, sensory-specific satiety may be enhanced by increased attention toward the sensory properties of one's food.

Research suggests that sensory-specific satiety reduces both liking and 'wanting' for eaten foods (Havermans et al., 2009; Balleine & Dickinson, 1998). Liking refers to the feelings of pleasure we experience when consuming a substance whereas 'wanting' is a form of motivation. 'Wanting' is triggered by reward-related cues and experienced as craving or desire (Berridge & Robinson, 2016; Robinson & Berridge, 1993). As such, if sensory eating increases sensory-specific satiety, we would expect to see it lead to reduced 'wanting' and liking for the same or similar foods but not for different foods. For example, following consumption of sweet foods we should see reduced desire for, and liking and consumption of, other sweet foods but no change in desire for, and liking and consumption of, savory foods.

Prioritization of Sensory Pleasure

Another possible explanation for the effects of sensory eating is that it leads people to prioritize sensory pleasure over satiation which in turn reduces the quantity they eat. Sensory-specific satiety means we obtain most pleasure during the early stages of eating a food but less pleasure as we eat more of it. Indeed, with continued consumption, a positive affective response can turn into a negative one (Hetherington & Havermans, 2013). For example, a large bar of chocolate may taste divine at the first bite but sickly with the last. Focusing on the sensory properties of a food may better attune a person to this decline in pleasure leading them to stop eating sooner than they might have done otherwise. Research by Cornil and Chandon (2016) supports the notion that thinking about the sensory properties of food can influence food-related decisions. They found that participants who were asked to vividly imagine the taste, smell and texture of three different palatable foods selected a smaller portion of a fourth palatable food. However, this effect only occurred among hungry participants who were not dieting to lose weight; participants who were dieting or were not hungry chose smaller servings regardless. Thus, in a similar manner, sensory eating may reduce consumption by prompting one to prioritize sensory enjoyment over feelings of satiation, though these effects may only emerge where the person would ordinarily have focused on satiation, in other words, when hungry and not consciously restricting their intake because of diet-related goals. As such, we may only see effects of sensory eating on hungry participants who are not dieting to lose weight. We may also see higher levels of reported enjoyment and prioritization of pleasure among those who engage in sensory eating.

Activation of Health-Related Goals

Sensory eating could also influence behavior by increasing awareness of the nutritional properties of a food which could in turn activate health-related goals. For example, noticing the sweetness of a food might raise awareness of its sugar content which could in turn remind a person (either consciously or unconsciously) that they are trying to lose weight or eat more healthily. Literature on goal priming is relevant here. Goal priming is where environmental stimuli associated with specific goals activate these goals as well as behaviors that help the person achieve them (Custers & Aarts, 2005; Papies & Aarts, 2016). For example, Papies and Hamstra (2010) found that the presence of a poster on a shop door promoting a low-calorie recipe led participants who were concerned about weight management to eat fewer free snack samples. Priming refers to instances where the person is not consciously aware of the link between the stimuli and their behavior. This is believed to be important as conscious awareness can sometimes undermine effects (Bargh, 2016). However, effects can still occur even where a person is aware of the link. Indeed, one could argue that more, rather than less, conscious, reflective processing would allow for better alignment between goals and behavior (Tapper & Ahmed, 2018). Nevertheless, in terms of the present study, the implications are the same regardless of whether effects occur via conscious or unconscious processes; if sensory eating influences consumption via activation of health-related goals, we are likely to see different effects for foods that are perceived as more or less healthy. We would also expect effects to be stronger for people who are dieting to lose weight or trying to eat more healthily.

Slowed Eating

Slower eating is associated with reduced food intake (Robinson, Almiron-Roig et al., 2014). This may occur for several reasons. First, slower eating may increase portion size memory accuracy (Hawton et al., 2019); as described above, memory for food eaten can inform subsequent decisions about how much food to eat. However, since sensory eating does not appear to enhance memory for food eaten (see above) this cannot explain its effects. A second reason for the association between eating rate and food intake is that slower eating increases orosensory exposure (the length of time food is in the mouth) which in turn promotes the release of gut hormones that reduce appetite (Hawton et al., 2019; Krop et al., 2018; Ting et al., 2021). Thus, sensory eating could reduce intake by slowing down the rate of eating and increasing orosensory exposure. If this were the case, we would expect it to be associated with reduced appetite. We may also see stronger effects in situations where people are inclined to eat more quickly, for example when hungry or when eating a highly palatable food (Hill & McCutcheon, 1984).

The Current Research

This paper describes a series of four laboratory studies, the aims of which were two-fold. First, the studies attempted to replicate findings from previous research that have shown effects of sensory eating on subsequent food intake. Second, the studies explored the mechanisms described above. Each of the studies followed the same broad procedure but with modifications aimed at exploring different potential mechanisms of action. In Study 1, participants were asked to eat one chocolate chip cookie, whilst listening to an audio recording that either directed their attention toward the cookie's sensory properties or described how cookies were made. Ten to 15 minutes later they were provided with two highly palatable foods of contrasting taste: crisps and cookie pieces. They were asked to taste and rate these on a series of dimensions. Importantly, at this point they were left alone for 5 minutes and told they could eat as much of the snacks as they wanted as the remainder would be thrown away. The amount they ate served as the main dependent variable for the study. Additional measures were also included to assess motivation for the snacks as a mediator and hunger as a moderator. Study 2 followed a similar procedure but attempted to eliminate any effects of distraction that may have occurred in the control group in Study 1 by removing the audio instructions from the control condition. It also controlled eating rate across the experimental and control conditions during the sensory eating manipulation by instructing participants to eat one mouthful of food each time they heard a 'beep'. The foods employed were chocolate for the manipulation and two foods with different levels of perceived healthiness for the measure of consumption: chocolate and whole, unblanched almonds. Measures relating to prioritization of sensory pleasure were also taken. However, in this study there were no significant effects of the sensory eating manipulation. For this reason, Studies 3 and 4 retained the eating rate control group but introduced a third condition in which eating rate was not controlled. This modification was designed to examine the possibility that effects were driven by slowed eating. The foods employed were chocolate followed by cookie pieces and almonds in Study 3 and cookie pieces, followed by cookie pieces and crisps in Study 4. In Study 4, a webcam was also used to assess eating rate during the consumption measure and hunger was assessed as a mediator as well as a moderator. Both Studies 3 and 4 also included measures of sensory eating during the manipulation (as a manipulation check) and during the consumption measure (to explore the possibility of continued sensory eating). Finally, data across the four studies were combined to provide an overall effect size and to explore moderation by hunger and dieting status.

Transparency and openness

For all four studies we report how we determined our sample size, and we report all data exclusions (if any), all manipulations and all measures. Studies 1 to 3 were not preregistered but the design, hypotheses and analyses plan for Study 4 was pre-registered at https://osf.io/xbjpt (Tapper, Hinton, Ferriday & Seguias, 2018) prior to study commencement. All study materials can be requested from the authors and data for all four studies are available at https://osf.io/6ajdr/ (Tapper, Hinton, Ferriday & Seguias, 2024). Data were analyzed using IBM SPSS Statistics (Version 28), JASP (Version 0.18.3, JASP Team, 2024) and the PROCESS macro for SPSS (Version v4.3, Hayes, 2013).

Study 1

The two key mechanisms of action explored in this study were weakened conditioned associations and increased sensory-specific satiety. If sensory eating exerts its effects via either of these mechanisms, we would expect to see reduced motivation, or ‘wanting’, for the target food. According to incentive-sensitization theory, ‘wanting’ is often associated with automatic psychomotor activation of approach behaviours as well as conscious feelings of craving or desire (Berridge & Robinson, 2016; Robinson & Berridge, 1993). Thus, if sensory eating reduces motivation for the target food, this may be reflected in both reduced reported desire and reduced automatic approach.

In this study we used an approach-avoidance task to measure automatic approach. Approach-avoidance tasks have been used extensively in the field of addiction to measure approach bias toward alcohol- and cigarette-related cues (Loijen, Vrijsen, Egger, Becker & Rink, 2020). They have also been used in the food domain, where food approach bias sometimes (but not always) correlates with measures of general state food craving (Lender, Meule, Rinck, Brockmeyer, & Blechert, 2018; Meule, Lender, Richard, Dinic & Blechert, 2019; but see also Meule et al., 2020; Kahveci, Meule, Lender, & Blechert, 2020). However, importantly for the current study, approach bias for individual foods has also been found to correlate with participants' desire to eat those specific foods, suggesting the measure may be sensitive to different levels of desire between foods, rather than simply reflecting broader physiological states such as hunger (Kahveci et al., 2020). In the current study we used a type of food-related approach-avoidance task that has previously been shown to be sensitive to a mindfulness-based manipulation (Papies, Barsalou & Custers, 2012). We also assessed participants' subjective feelings of desire by asking them to rate the extent to which they would like to eat specific foods (Stevenson, Francis, Attuquayefio, Ockert, 2017).

If sensory eating reduces motivation for food, this may be reflected in reduced approach bias and reduced ratings of desire to eat. According to the sensory-specific satiety account, these effects would apply to the food targeted in the sensory eating manipulation as well as foods of similar taste. However, effects would not extend to foods of contrasting taste. According to the weakened conditioned association account, we would also expect to see effects on the targeted food. However, there is insufficient evidence to allow us to predict whether such an effect would be limited to the target food only, would extend to similar foods or would generalize to food overall.

Cookies were used for the sensory eating manipulation in this study, and cookies and crisps for the consumption measure. Thus, in terms of consumption, if effects occur because of increased sensory specific satiety, we would expect to see reduced consumption of cookies but not crisps. This pattern of effect would also be consistent with weakened conditioned associations, but again, there is an absence of evidence to allow us to rule out the possibility that effects could generalize to the broader category of food and eating, in which case we may see reduced consumption of both cookies and crisps.

Method

Participants. Our sample size was informed by Seguias and Tapper (2018) who, in a similar study, found an effect size of partial $\eta 2$ = 0.27 (*d* = 1.14) between an experimental and control condition. There was an absence of previous data to inform a potential condition x food type interaction effect size. For this reason, we used G*Power to calculate the sample size needed to detect a significant difference (with a large effect size, *d* = 1.14) between two independent groups (α = 0.05, 80% power). This indicated a required sample of 28. We then approximately doubled this to allow for the exploration of an additional interaction effect. A total of 60 participants (38 females, 22 males) with an average age of 28 years (*SD* = 10) took part in the study in 2016 in return for 5 pounds Sterling. Participants were recruited via an advertisement on an online platform affiliated with City, University of London as well as via flyers placed on billboards around the university campus. To avoid participants guessing that food consumption was being measured, the adverts and information sheet stated that the study related to '*Food Preferences and Taste Perception*.' To take part, participants had to be fluent in English and should not have taken part in a related study. City, University of London Psychology Department Research Ethics Committee approved the study.

Foods and consumption measure. For the sensory eating manipulation, participants were provided with one whole 13 g Sainsbury's chocolate chip cookie (53 kcal). For the measure of consumption, administered 10-15 minutes later, participants received 30 g Walker's Ready Salted crisps (158 kcal) and 60 g Sainsbury's chocolate chip cookies (245 kcal). Note that the weight of cookies provided in this second ad libitum snack differed from the weight of the crisps. This was because, for the purpose of the cover story, it was felt that it was more important that the two portions looked visually equivalent. The cookies were also broken into smaller pieces to avoid participants keeping track of the number they had eaten. Both portions of food were presented on separate plates as part of a bogus ‘taste test’ in which participants were given a paper questionnaire that asked them to rate their liking of the foods as well as how sweet and salty they found them. The taste test was part of the cover story, so the ratings were not analyzed. However, the order in which participants were asked to taste and rate the foods (either crisps first or cookies first) was counterbalanced across condition and gender. Participants were left alone for 5 minutes to complete the taste test and were told by the researcher that they could eat as much as they liked as anything remaining would be thrown away. At the end of the study the total amount eaten was calculated by weighing the leftovers.

Experimental manipulation. The study used two audio recordings played from a computer. In the experimental condition the recording was 82 seconds long and encouraged participants to focus on the sensory properties of the cookie. In the control condition the recording was 79 seconds long and described the steps involved in making cookies (see Appendix 1 for full transcript of the audio recordings).

Additional measures.

Hunger. Participants were asked *How hungry are you at the moment?* They answered using a 100-point visual analogue scale anchored by *Not hungry at all* and *Extremely hungry*. The study also included three additional questions relating to times participants last ate and next expected to eat, as well as how much of their favorite food they could eat. These were originally intended to be combined with the hunger question to provide an overall hunger score, as per Grand (1968). However, these three additional questions were dropped from the analysis in light of more recent evidence from Rogers and Hardman (2015) that the single item rated before exposure to the food provides a more accurate assessment.

Pleasure rating. Participants were asked *How much pleasure did you get out of eating the cookie?* They rated this on a scale of 1 to 5, anchored by *None at all* and *A lot* respectively. This question was used to check that the level of pleasure experienced was similar across conditions.

Approach avoidance task (AAT). This was employed as a measure of implicit desire. It used 15 images of different types of food: 5 highly palatable sweet items, including a cookie, 5 highly palatable salty items, including crisps, and 5 neutral items (for example, plain yogurt). It also included 15 images of stationery items (for example, a highlighter pen or an eraser) as fillers. Each image was displayed four times, twice in a blue frame and twice in a purple frame, forming a total of 120 trials that were presented in a new random order for each participant. Participants were asked to press the letter L on the keyboard if the image was in a blue frame and the letter S if it was in a purple frame. Images in a blue frame represented the approach condition and became larger when the letter L was pressed. Images in the purple frame represented the avoidance condition and became smaller when the letter S was pressed. If participants pressed the wrong key in either condition, an error message was displayed before the task continued. Participants were asked to complete the task as quickly and accurately as possible and response times, in milliseconds, were recorded for each trial. Trials with errors were excluded prior to analyses. The task was scored by subtracting mean response times to approach trials from mean response times to avoid trials such that a higher positive score meant participants were quicker to ‘approach’ the item whilst a higher negative score meant they were quicker to ‘avoid’ the item. Separate scores were calculated for sweet items, salty items, and cookies. Prior to the main experimental phase, participants completed 20 practice trials that used the images of stationery.

Food rating task. To assess explicit desire, participants were shown the same 15 food images used in the approach avoidance task and were asked to *Imagine you were offered this food right now. How much would you want to eat it?* They responded on a scale from 1 to 5, anchored (i.e. with just two descriptors at the ends of the scale) by *Not at all* and *Very much* respectively. The images were presented in a new random order for each participant.

Procedure. Men, and, separately, women, were alternately allocated to conditions. They were seated in front of a computer where they completed the hunger measure before being given the whole cookie to eat whilst listening to their assigned audio recording. They then completed the pleasure rating followed by the approach avoidance and food rating tasks. The order of these latter two tasks was counterbalanced across conditions. Immediately after this they moved to a different table to complete the bogus taste test then a funneled suspicion probe to determine whether they had guessed the true aim of the study (i.e., that their food consumption was being measured). Finally, they were debriefed, and provided details of their gender, age, whether they were currently dieting to lose weight, and whether they were left- or right-handed (since the approach response in the AAT was associated with the right hand). They also provided consent for the consumption measure.

Results

Two participants were excluded because of technical errors with the audio recording during the laboratory session and one was excluded because they guessed their food consumption was being measured. The remaining 57 participants were well-matched across conditions (Table 1).

Table 1

Characteristics of Study Participants as a Function of Condition

Characteristic	Sensory eating (*n* = 29)	Control (*n* = 28)
Females (%)	66%	61%

Mean age in years (*SD*)	28 (9)	28 (11)
Dieting to lose weight (%)	28%	21%
Mean hunger (*SD*)	43 (24)	51 (27)
Mean pleasure rating (*SD*)	4 (1)	4 (1)
Left-handed (%)	0%	7%

Effect of condition on food consumption. The amount of cookies and crisps eaten during the taste test by participants in the sensory eating and control conditions is shown in Table 2. Non-normal distributions were corrected using square root transformations and a 2(condition) x 2(food type) mixed ANOVA was used to explore effects. In line with the study's hypothesis, this showed a main effect of condition on the amount of food eaten $F(1,55) = 17.92$, $p < .001$, partial $\eta 2 = 0.25$, with those in the sensory condition eating significantly less than those in the control condition. However, there was no significant interaction between condition and food type, $F(1,55) = 0.01$, $p = 0.94$, $\eta 2 = 0.00$. Additional Bayesian analysis showed $BF_{10} = 0.057 \pm 2.83\%$ providing substantial evidence (Dienes, 2014) that sensory eating did not reduce cookie consumption to a greater extent than crisp consumption. There was also no main effect of food $F(1,55) = 0.102$, $p = 0.75$, partial $\eta 2 = 0.00$. The same pattern of effects and effect size (partial $\eta 2 = 0.27$) was found when excluding participants who were dieting to lose weight (n = 43).

Table 2

Mean (SD) Grams of Cookies and Crisps Eaten in the Sensory Eating and Control Conditions

Food type	Sensory eating (*n* = 29)	Control (*n* = 28)
Cookies (g)	16 (17)	27 (13)
Crisps (g)	16 (13)	29 (16)
Total (g)	33 (24)	56 (20)

Effect of condition on AAT scores. For sweet food images, mean scores were -48 (*SD* = 289) for the sensory eating condition and 45 (*SD* = 206) for the control condition. For salty food images they were 58 (*SD* = 260) and -34 (*SD* = 210) respectively. A mixed 2(condition) x 2(food type) ANOVA found no significant effect of condition, $F(1,55) = 0.00$, $p = 0.99$, partial $\eta 2 = 0.00$, no significant effect of food type, $F(1,55) = 0.76$, $p = 0.78$, partial $\eta 2 = 0.001$, and no significant interaction, $F(1,55) = 3.53$, $p = 0.65$, partial $\eta 2 = 0.060$. Bayesian analysis for the predicted main and interaction effects showed $BF_{10} = 0.225 \pm 1.48\%$, $BF_{10} = 0.206 \pm 1.20\%$, and $BF_{10} = 0.200 \pm 53.42\%$ respectively, indicating substantial evidence for the null hypotheses.

Data for the cookie image showed a non-normal distribution so bootstrapping, with 5,000 resamples, was used for the analysis. The means were in the predicted direction, -105, (*SD* = 662) for the sensory eating condition and 113 (*SD* = 403) for the control condition, but a one-way ANOVA found that this difference was not statistically reliable and of a small effect size $F(1,56) = 2.23$, $p = 0.14$, $\eta 2 = 0.039$. For all analyses, the same pattern of effects was found when excluding dieters ($n = 43$) and when excluding participants who were left-handed ($n = 55$).

Effect of condition on food rating scores. Mean desire ratings for images of sweet foods were 2 (*SD* = 1) in the sensory eating condition and 2 (*SD* = 1) in the control condition. For images of salty foods, they were 3 (*SD* = 1) and 3 (*SD* = 1) respectively. Consistent with literature on sensory-specific satiety, a mixed 2(condition) x 2(food type) ANOVA showed that desire for sweet foods was significantly lower than desire for salty foods, $F(1,55) = 27.59$, *p*

<.001, partial $\eta 2$ = 0.334. However, there was no main effect of condition, $F(1,55) = 0.13$, p = 0.72, partial $\eta 2$ = 0.002, and, contrary to predictions, no significant interaction between condition and food, $F(1,55) = 0.24$, $p = 0.63$, partial $\eta 2$ = 0.04. Bayesian analysis for the latter showed substantial evidence for the null hypothesis; $BF_{10} = 0.083 \pm 2.65\%$.

For ratings of the cookie image, mean scores were 3 (SD = 1) for the sensory eating condition and 3 (SD = 2) for the control condition. A one-way ANOVA, with 5,000 bootstrap resamples, found no significant difference between conditions $F(1,56) = 0.046$, $p = 0.83$, $\eta 2$ = 0.001. Again, Bayesian analysis showed substantial evidence for the null hypothesis; BF_{10} = 0.273 ± 0.009%. When excluding dieters, the same pattern of effects was found across all analyses.

Moderation by hunger. Hierarchical bootstrap linear regression (with 5,000 bootstrap resamples) was used to explore whether the effect of condition on total cookie and crisps intake was moderated by hunger. Hunger was entered at step 1, condition at step 2 and the interaction term at step 3. Results showed no main effect of hunger on intake (b = 0.04, $SE\ B$ = 0.13, β = 0.04, p = .77) and no interaction between condition and hunger (b = -0.17, $SE\ B$ = 0.22, β = -0.19, p = .42). The pattern of effects did not change when dieters were excluded.

Discussion

The findings showed a significant reduction in intake (of 23g) in the sensory eating condition, supporting previous studies that have also shown reductions in intake (Allirot et al., 2018; Arch et al., 2016; Higgs & Donohoe, 2011; Mantzios et al., 2020; Robinson et al., 2014b; Seguias & Tapper, 2018). However, the results suggest that this was not driven by increased sensory specific satiety. The food ratings indicated that participants likely experienced some sensory specific satiety for sweet foods following the manipulation because their self-reported desire was significantly lower for sweet foods than for salty foods. Nevertheless, there were no interactions between condition and food type across any of the measures, with Bayes factors indicating that the sensory eating manipulation did not increase sensory specific satiety.

There were also no significant main or interaction effects on the AAT, with Bayes factors indicating substantial evidence for the null hypothesis. The absence of a main effect of food type is inconsistent with the view that sensory-specific satiety reduces ‘wanting’ (Havermans et al., 2009; Balleine & Dickinson, 1998). However, it is possible that the AAT did not index ‘wanting’. Some research has suggested that other types of AAT are more sensitive to changes in ‘wanting’ compared to the version used in the present study (Kahveci, van Alebeek, Berking & Blechert, 2021). Others have suggested that the AAT is more a measure of habitual responses (Watson, de Wit, Hommel & Wiers, 2012; see also Tibboel, De Houwer & Van Bockstaele, 2015). Nevertheless, in the present study, exploratory analyses of the small number of trials that used a cookie image (i.e. the target food) were in the predicted direction, with those in the sensory eating group showing a non-significantly lower approach bias for cookies compared to those in the control condition. This pattern of results is consistent with the hypothesis that sensory eating weakens conditioned associations (and therefore ‘wanting’) for the specific food that has been eaten. As such, future research could explore the possibility that sensory eating reduces approach bias, but for the target food only. Such research would also benefit from including a baseline measure prior to the manipulation.

To summarize, Study 1 replicated previous studies that have shown reductions in intake following sensory eating but indicated that this effect was unlikely to be driven by increased sensory specific satiety. More research would be needed to explore the possibility that the effect is driven by weakened conditioned associations.

Study 2

In Study 1, during the sensory eating manipulation, an audio recording describing how cookies were made was used to control for the extent to which participants in the two conditions were thinking about cookies. However, it is possible that this functioned as a form of distraction in the control group, drawing participants' attention away from the physical act of eating. This potential source of distraction was therefore removed in Study 2. Procedures were also introduced to control for speed of eating across the two conditions.

Additionally, Study 2 also explored two other potential mechanisms of action - prioritization of sensory pleasure and activation of health-related goals. The former was explored with the introduction of self-report measures asking participants about how much they enjoyed / tried to enjoy the food during the taste test. The latter was explored by comparing consumption of 'unhealthy' chocolate and 'healthy' almonds in the taste test. If reductions in intake occur because participants are reminded of their health-related goals, we would expect to see reductions in intake of chocolate but not almonds.

Method

Participants. The rationale for our sample size was similar to Study 1; the condition effect size from Study 1 was partial $\eta 2$ = 0.25 (d = 1.04, i.e. a large effect) which G*Power indicated required a total sample size of 32 participants to detect a difference between two independent groups. We then approximately doubled this to allow for the exploration of additional interaction effects. A total of 61 participants (45 females, 16 males) with an average age of 27 years (SD = 11) took part in the study in 2017 in return for 5 pounds Sterling. Recruitment procedures were as per Study 1 though participants were also screened to ensure they had no food allergies or dietary restrictions that would prevent them from eating the foods provided. Ethics approval was granted by City, University of London Psychology Department Research Ethics Committee.

Foods and consumption measure. For the sensory eating manipulation participants were provided with 12 Cadbury chocolate buttons (11 g, 59 kcal). The consumption measure was the same as in Study 1 except that the foods comprised 60 g Cadbury chocolate buttons (320 kcal) and 60 g whole, unblanched almonds (376 kcal).

Experimental manipulation. Participants in both conditions listened to an audio recording that played a series of 12 beeps at 15 second intervals. They were instructed to eat one piece of chocolate every time they heard a beep. Participants in the sensory eating condition also heard an additional instruction after each beep that asked them to attend to the different sensory properties of the chocolate (see Appendix 2 for full transcript of the audio recording).

Additional measures.

Pleasure experience and prioritization. Using a series of 100-point visual analogue scales, participants were asked to rate the chocolate and almonds used in the taste test as follows: (a) *How much pleasure did you get from eating the [chocolate buttons / almonds] just now?* (anchored by *[I didn't get any / I got a lot of] pleasure from eating the [chocolate buttons / almonds]*) and (b) *How much did you try to enjoy the [chocolate buttons / almonds] just now?* (anchored by *[I didn't try / I really tried] to enjoy the chocolate buttons / almonds*).

Perceived healthiness. Participants used a 100-point visual analogue scale to respond to the question *How healthy would you consider the [chocolate buttons / almonds?]* (anchored by *Not at all healthy / very healthy*).

Strategy use questionnaire. Participants in the experimental group were told *Toward the start of the study you were given some chocolate and asked to focus on its sensory properties as you ate it (for example its smell, taste, and texture)*. They were then asked to use two 100-point visual analogue scales to respond to the questions *To what extent did you [continue to] do this as you ate the [chocolate / almonds] just now?* The scales were anchored by *I did not do this at all* and *I did this all the time I was eating the [chocolate / almonds]*. Participants answered in relation to the chocolate first, then the almonds.

Procedure. Participants used a computer to answer questions about hunger (as per Study 1). They were then presented with 15 food images (including one of each of the target foods, i.e. almonds and chocolate buttons) and asked to rate how much they would enjoy eating them. These questions were originally included to further explore sensory specific satiety, however, given the null findings in Study 1 (and the pattern of findings across the four studies), and for the sake of simplicity, description of these data have been omitted. After rating these images, participants indicated their age, first language and gender. The software then randomized them to the experimental or control condition, stratifying by gender. They were then given a bowl of 12 chocolate buttons which they ate as instructed by the relevant audio recording. Following this they rated the 15 food images for a second time, completed a personality measure (the data for which are not presented here) and then the bogus taste test. After this they used a pen and paper to complete the ratings of pleasure and perceived healthiness (first in relation to the chocolate and then the almonds) and the strategy use questionnaire. They also indicated whether or not they were dieting to lose weight. Finally, they underwent a funneled suspicion probe, were debriefed about the aims of the study and provided consent for the food consumption measure.

Results

No participants guessed their food intake was being measured but one participant was excluded due to technical errors with the audio recording. As shown in Table 3, the remaining 60 participants were well-matched on a range of characteristics.

Table 3

Characteristics of Study 2 Participants as a Function of Condition

Characteristic	Sensory eating (*n* = 33)	Timed control (*n* = 27)
Females (%)	76	70
Age in years (*M*, *SD*)	28 (10)	26 (12)
English as first language (%)	67	63
Dieting to lose weight (%)	3	4
Hunger (*M*, *SD*)	41 (25)	44 (25)

Analysis of the perceived healthiness ratings confirmed that participants perceived the almonds as significantly healthier than the chocolate (M = 76, SD = 21, M = 14, SD = 19 respectively, and $t(59) = 16.76$, $p < .001$, with 5,000 bootstrap resamples to correct for skewed distributions).

Effect of condition on food consumption. The total amounts of chocolate and almonds eaten are shown in Table 4. Log transformations were applied to correct non-normal distributions but, contrary to predictions, a 2(condition) x 2(food type) ANOVA showed no main effect of condition on the amount of food eaten, $F(1,58) = 0.26$, $p = 0.62$, partial $\eta 2 = .004$ and no interaction between condition and food type, $F(1,58) = 0.04$, $p = 0.85$, partial $\eta 2 = .001$. There was also no main effect of food, $F(1,58) = 0.04$, $p = 0.84$, partial $\eta 2 = .001$. Bayesian analysis showed substantial support for the null hypothesis for both the main effect of condition, $BF_{10} = 0.307 \pm 0.78\%$ and the interaction, $BF_{10} = 0.037 \pm 3.05\%$. The same pattern of effects was found when excluding dieters (n = 58).

Table 4

Mean (SD) Grams of Chocolate and Almonds Eaten in the Sensory Eating and Control Conditions in Study 2.

Food type	Sensory eating (*n* = 33)	Timed control (*n* = 27)
Chocolate	10 (10)	13 (14)
Almonds	10 (8)	10 (8)
Total	20 (15)	23 (17)

Effect of condition on attempted enjoyment and pleasure. Mean attempted enjoyment ratings for chocolate were 56 (*SD* = 28) and 59 (*SD* = 28) for participants in the experimental and control conditions respectively and for almonds they were 53 (*SD* = 32) and 63 (*SD* = 28) respectively. Mean pleasure ratings for chocolate were 56 (*SD* = 28) and 64 (*SD* = 31) for those in the experimental and control groups respectively and for almonds they were 52 (*SD* = 29) and 53 (*SD* = 28) respectively. Two mixed ANOVAs confirmed that there was no main of effect of condition on either attempted enjoyment, $F(1,58) = 1.19$, $p = .28$, partial $\eta 2 = 0.020$ or pleasure $F(1,58) = 0.86$, $p = .36$, partial $\eta 2 = 0.015$. There were also no interactions between condition and food type for either attempted enjoyment $F(1,58) = 0.62$, $p = .43$, partial $\eta 2 = 0.011$ or pleasure $F(1,58) = 0.40$, $p = .53$, partial $\eta 2 = 0.007$. Additionally, there were no main effects of food type for either attempted enjoyment $F(1,58) = 0.00$, $p = .99$, partial $\eta 2 = 0.000$, or pleasure $F(1,58) = 2.02$, $p = .16$, partial $\eta 2 = 0.034$. Bayesian analysis showed weak support for the null hypothesis for the main effect of condition on attempted enjoyment, $BF_{10} = 0.424 \pm 0.78\%$ but substantial support for the null hypothesis for the interaction between condition and food on enjoyment, $BF_{10} = 0.031 \pm 4.53\%$, the main effect of condition on pleasure, $BF_{10} = 0.032 \pm 8.34\%$, and the interaction between condition and food on pleasure, $BF_{10} = 0.053 \pm 2.97\%$

Moderation by hunger. Hierarchical bootstrap linear regression (with 5,000 bootstrap resamples) was used to explore whether the effect of condition on total food intake was moderated by hunger. Hunger was entered at step 1, condition at step 2 and the interaction term at step 3. Results showed that participants who were hungrier ate significantly more (b = 0.26, *SE B* = 0.09, β = 0.41, p = .011) but there was no interaction between condition and hunger (b = -0.07, *SE B* = 0.19, β = -0.13, p = .71). The pattern of effects did not change when dieters were excluded.

Continued strategy use in the experimental condition. Mean ratings of the extent to which participants in the experimental condition (n = 33) continued to apply the sensory eating strategy during the taste test were 52 (*SD* = 28) for the chocolate and 50 (*SD* = 27) for the almonds. Pearson's correlations (with 5,000 bootstrap resamples) showed that the higher the participant's rating of continued strategy use, the less chocolate they ate (r = -46, p = .007). However, there was no such relationship for almonds (r = -.04, p = .82).

Discussion

The results of Study 2 showed no main effect of condition on intake and no interaction between condition and food type on intake. This suggests the effects in Study 1 resulted from either (a) distraction in the control condition and/or (b) differences in rate of eating across the two conditions during the sensory eating manipulation. However, it is also possible that the chocolate employed in Study 2 was a less effective target for sensory eating compared to the chocolate chip cookies used in Study 1. This may have occurred because there is less variation in look, taste and texture in chocolate compared to a chocolate chip cookie, i.e. a reduced range of stimuli to attend to. This in turn may have reduced the extent to which participants engaged with the strategy.

Study 3

In light of the non-significant effects in Study 2, Study 3 replicated the general procedure but introduced an additional condition in which eating rate was not controlled. To reduce variability in the main consumption measure, recruitment was also restricted to just one sex (females). Additionally, the target food was switched back to cookies (as per Study 1) and extra measures were introduced to assess level of sensory eating during the manipulation and the taste test.

Method

Participants. Our sample size rationale was as per Study 2. A total of 90 females with an average age of 21 years (*SD* = 4) took part in exchange for 5 pounds Sterling between 2017 and 2018. Recruitment procedures were as per Study 2. City, University of London Psychology Department Research Ethics Committee, provided ethical approval.

Foods and consumption measure. For the sensory eating manipulation participants were provided with 6 mini Maryland chocolate chip cookies (totaling 20 g, 100 kcal). Each cookie was cut in half to make 12 pieces. The consumption measure was the same as in Study 1 except the foods comprised 60 g mini Maryland chocolate chip cookies cut in half (300 kcal) and 60 g whole almonds (376 kcal).

Experimental manipulation. The manipulation was the same as Study 2 except the instructions in the sensory eating condition were adjusted to refer to ‘cookie’. There was also a third condition in which participants did not hear any beeps or sensory eating instructions but were simply asked to eat the cookies.

Additional measures.

Manipulation check. Participants were asked *Whilst eating the cookies toward the start of the study, to what extent did you pay attention to their smell, taste and texture?* They answered using a 0 to 10 point Likert scale anchored by *I didn't do this at all* and *I did this all the time I was eating the cookies*.

Attention to pleasure. Two 100-point visual analogue scale items asked participants *To what extent were you thinking about the pleasurable qualities of the [cookies / almonds] as you ate them just now?* These were anchored by *I did not do this at all* and *I did this all the time I was eating the [cookies / almonds]*.

Sensory eating during the taste test. Two 100-point visual analogue scales asked participants *Whilst eating the [cookies / almonds] just now, to what extent did you pay attention to their smell, taste, and texture?* (anchored as per the attention to pleasure items). These were included to explore continued sensory eating as a potential mediator of effects.

Procedure. The procedure followed Study 2 but with the following adjustments: (1) participants were randomized to three conditions instead of two, (2) they completed the manipulation check immediately following the 5-minute taste test (3) the pleasure ratings were replaced by the attention to pleasure items and the continued sensory eating measures.

Results

No participants guessed their food intake was being measured, and as shown in Table 5, participants were well-matched across conditions except for minor differences in relation to dieting status and hunger.

Table 5

Characteristics of Study 3 Participants as a Function of Condition

Characteristic	Sensory eating (*n* = 32)	Timed control (*n* = 29)	Untimed control (*n* = 29)
Age in years (*M*, *SD*)	20 (2)	21 (5)	21 (4)
English as a first language (%)	72%	72%	76%
Dieting to lose weight (%)	9%	3%	10%
Hunger (*M*, *SD*)	42 (24)	43 (24)	35 (22)

The manipulation check data (that used a scale from 0 to 10) showed food attention rating means (*SD*s) of 9 (2) in the sensory eating group versus 5 (3) in the timed control group and 6 (3) in the untimed control group. A one-way ANOVA showed a significant group difference, $F(2,89) = 19.64$, $p < .001$, partial $\eta 2 = 0.311$, with follow-up t-tests confirming that those in the sensory eating group reported paying more attention to the sensory properties of the first cookie snack compared to those in the timed control group, $t(59) = 6.01$, $p < .001$, $d = 2.63$, or the untimed control group, $t(59) = 4.77$, $p < .001$, $d = 2.59$. There was no significant difference between the timed and untimed control groups $t(56) = 1.24$, $p = .22$, $d = 2.86$. Analysis also confirmed that participants perceived the almonds as healthier than the chocolate ($M = 79$, $SD = 22$, $M = 10$, $SD = 15$ respectively, and $t(89) = 22.13$, $p < .001$, $d = 2.97$, with 5,000 bootstrap resamples to correct for skewed distributions).

Effect of condition on food consumption. Total amounts of cookies and almonds eaten are shown in Table 6. A 3(condition) x 2(food type) ANOVA showed a significant main effect of condition on the amount of food eaten, $F(1,87) = 6.13$, $p = 0.003$, partial $\eta 2 = .124$ and no interaction between condition and food type, $F(2,87) = 0.14$, $p = 0.87$, partial $\eta 2 = .003$. There was also no main effect of food type, $F(2,87) = 1.58$, $p = 0.21$, partial $\eta 2 = .018$. Follow-up t-tests (with 5,000 bootstrap resamples) found that the sensory eating group ate significantly less than the untimed control group, $t(59) = 3.45$, $p < .001$, $d = 0.87$, but not less than the timed control group, $t(59) = 1.57$, $p = .12$, $d = 0.35$, $BF_{10} = 0.736 \pm 0.01\%$. There was no significant difference between the timed and untimed control groups, $t(56) = 1.88$, $p = .064$, $d = 0.54$, $BF_{10} = 1.147 \pm 0.01\%$. When dieters were excluded, the difference between those in the timed and untimed control groups became significant, $t(52) = 2.29$, $p = .025$, $d = 0.61$, $BF_{10} = 2.29 \pm 0.01\%$; $M = 21$, $SD = 12$, $n = 28$ and $M = 29$ $SD = 14$, $n = 26$ respectively. However, the pattern of effects for other analyses remained unchanged (total $n = 83$).

Table 6

Mean (SD) Grams of Cookies and Almonds Eaten in the Sensory Eating, Timed Control and Untimed Control Conditions in Study 3

Food type	**Sensory eating (*n* = 32)**	**Timed control (*n* = 29)**	**Untimed control (*n* = 29)**
Cookies	9 (9)	11 (9)	15 (11)
Almonds	7 (5)	10 (8)	13 (8)
Total	17 (11)	21 (12)	28 (14)

Effect of condition on attention to pleasure. Mean attention to pleasure ratings for cookies were 52 (*SD* = 31), 58 (*SD* = 29) and 51 (*SD* = 30) for participants in the sensory eating, timed control and untimed control conditions respectively. The equivalent figures for almonds were 48 (*SD* = 32), 44 (*SD* = 29) and 49 (*SD* = 34). A mixed ANOVA showed no main of effect of condition, $F(2,87) = 0.018$, $p = .98$, partial $\eta 2 = 0.000$, $BF_{10} = 0.084 \pm 0.97\%$ and no interaction between condition and food type, $F(2,87) = 0.62$, $p = .54$, partial $\eta 2 = 0.014$, $BF_{10} = 0.008 \pm 4.83\%$. The pattern of effects was the same when excluding dieters.

Sensory eating during the ad libitum snack. Mean ratings of the extent to which participants reported paying attention to the sensory properties of the cookies during the ad libitum snack were 63 (*SD* = 31), 51 (*SD* = 28) and 57 (*SD* = 27) for those in the sensory eating, timed control and untimed control conditions respectively. The equivalent figures for almonds were 67 (*SD* = 27), 54 (*SD* = 32) and 64 (*SD* = 27). A mixed ANOVA showed no main of effect of condition, $F(2,87) = 2.01$, $p = .14$, partial $\eta 2 = 0.044$, $BF_{10} = 0.532 \pm 0.86\%$, no main effect of food type $F(2,87) = 2.20$, $p = .14$, partial $\eta 2 = 0.025$, and no interaction between condition and food type, $F(2,87) = 0.22$, $p = .80$, partial $\eta 2 = 0.005$, $BF_{10} = 0.028 \pm 1.73\%$. Pearson's correlations also showed no relationship between participants' rated level of sensory eating during the taste test and the amount they ate, for either the cookies ($r = .05$, $p = .61$, $BF_{10} = 0.15$) or the almonds ($r = .01$, $p = .92$, $BF_{10} = 0.736 \pm 0.13$). When dieters were excluded the pattern of effects remained the same.

Moderation by hunger. Pearson's correlation showed no overall relationship between hunger and total amount of food eaten ($r = .05$, $p = .61$). A set of two hierarchical bootstrap linear regression models were used to explore whether hunger moderated the effect of condition on total food intake. Hunger and condition were entered at step 1, and the interaction term at step 2. The first model contrasted the sensory eating condition with the timed control group and showed no significant interaction between condition and hunger ($b = -0.16$, $SE\ B = 0.13$, $\beta = -0.38$, $p = .20$). The second model contrasted the sensory eating condition with the untimed control group and also showed no significant interaction between condition and hunger (b = -

0.23, *SE B* = 0.14, β = -0.45, *p* = .12). However, when dieters were excluded the latter contrast (*n*= 55) became significant (*b* = -0.31, *SE B* = 0.15, β = -0.63, *p* = .035). Further exploration with simple slopes analysis showed that when hunger was low (rated at 15, i.e., 1 *SD* below the mean), there was no significant effect of sensory eating (versus untimed eating) on total amount eaten (*b* = − 5.19, *SE B* = 4.73; *t* = − 1.10, *p* = .28). However, at mean and high levels of hunger (i.e., when rated at 39 and 62 respectively) sensory eating led to significant reductions in the amount eaten (*b* = − 12.64, *SE B* = 3.38; *t* = − 3.74, *p* = .0005 and *b* = − 20.09, *SE B* = 4.93; *t* = − 4.08, *p* = .0002 respectively). The Johnson-Neyman method indicated that the transition point occurred when hunger was rated at 23, with all scores above this point showing a significant effect of sensory eating on amount eaten.

Discussion

The results of Study 3 found that those in the sensory eating condition ate significantly less than those in the untimed control group, but not less than those in the timed control group. Given that rate of eating was matched between the sensory eating and timed groups, and assuming those in the untimed group ate faster, this would suggest that the effects of sensory eating may, at least in part, arise from it slowing eating down. The fact that equivalent reductions were observed for foods perceived as both healthy and unhealthy suggests effects did not occur due to priming of health-related goals. Likewise, we found no evidence that sensory eating increased prioritization of sensory pleasure.

Nevertheless, despite the absence of a significant difference between the sensory eating and timed control conditions, the means showed that the former ate non-significantly less than the latter (*d* = 0.35) with a Bayes factor indicating weak support for the null hypothesis (BF_{10} = 0.736 $\pm$ 0.01%). This raises the possibility of an additional mechanism underpinning effects of sensory eating. The self-report measures confirmed that those in the sensory eating condition paid more attention to the sensory properties of the food during the manipulation. However, there was no evidence that this increased attention carried over to the consumption measure (though with weak evidence for the null hypothesis, $BF_{10} = 0.532 \pm 0.86\%$).

Study 4

Study 4 aimed to replicate the effects of Study 3 but with greater power to detect a significant difference between the sensory eating and timed control groups. Reduced hunger following the manipulation was also assessed as a potential mechanism via which slowed eating could bring about reductions in intake. Additionally, eating rate during the consumption measure was recorded to examine the possibility of slowed eating carry over effects in the sensory eating condition that could be responsible for additional reductions in intake in the sensory eating condition relative to the timed control condition. The study took place over two sites and was pre-registered at https://osf.io/xbjpt, which includes the detailed hypotheses.

Method

Participants. Participants were recruited as per the previous studies but across both university sites. The target sample size of 180 was informed by Studies 1 and 3. It was powered to detect a difference in consumption of 12g (*SD* = 23) between each of the three conditions (*d* = 0.52, a medium effect). This was considered an appropriate compromise between potential effect sizes estimated from Studies 1 and 3 (which ranged from *d* = 0.35 to 1.04, see Tables 2 and 6), clinical significance and participant recruitment feasibility. A priori power analysis using G*Power ($\alpha = 0.05$, 80% power) indicated a required sample size of 60 participants per group. In our pre-registration we stated we would exclude and replace participants where they guessed their food intake was being measured or where they withheld consent for this. A total of 211 females took part in exchange for course credits or 5 (Bristol site) or 10 (City site) pounds Sterling. However, we excluded 18 participants who guessed their intake was being measured and 1 who withheld consent. We also excluded an additional 20 collected by one researcher due to researcher protocol errors (incorrect timing of the consumption measure) and a further 5 due to participant protocol deviations (4 did not eat the whole snack during the manipulation, 1 ate their own food during the study). Data collection took place between 2018 and 2020. Covid restrictions prevented us from recruiting additional participants and the final sample comprised 167 females with an average age of 26 years (*SD = 9*). The study received ethics approval at both sites (City, University of London Psychology Department Research Ethics Committee; University of Bristol School of Psychological Sciences Research Ethics Committee).

Foods and consumption measure. These were as per Study 3 except the almonds were replaced with 32.5 g of Walkers ready salted crisps (171 kcal).

Additional measures.

Hunger. Participants completed additional hunger ratings immediately following the manipulation and immediately following the consumption measure.

***Eating rate*.** Following previous research (Ferriday et al., 2016; Forde, van Kuijk, Thaler, de Graaf & Martin), eating rate during the consumption measure was assessed via webcam recordings. These were made as unobtrusive as possible; participants were unable to see an image of themselves at any point and the recording light on the webcam was turned off. The recordings were coded by four researchers (two per site) to provide the number of bites per minute from first bite to last bite. To assess inter-rater reliability, 43 videos (26%) were each coded independently by two researchers. Intraclass correlation coefficients (two-way mixed-effects absolute agreement) between coders ranged from 96 to 99%.

Procedure. The procedure was the same as Study 3 but with the addition of the extra hunger measures and the omission of the attention to pleasure measure. Webcam recording was started at the start of the testing session and stopped immediately prior to the suspicion probe, though only data relating to the consumption measure were coded. Additionally, dieting status was not collected at the Bristol site (*n* = 100 after exclusions).

Results

Deviations from the pre-registration. Where variables were not normally distributed, we used bootstrapping rather than transformations or non-parametric tests. For mediation analyses, instead of employing a series of linear models, as proposed by Baron and Kenny (1986), we followed more recent recommendations (Hayes, 2013) to estimate indirect effects. We also conducted additional Bayesian analyses, and some additional exploratory paired t-tests as indicated below.

Participant characteristics. Fewer participants in the untimed control condition had English as a first language. However, conditions were relatively well-matched in terms of age and hunger (see Table 7).

Table 7

Characteristics of Study 4 Participants as a Function of Condition

Characteristic	Sensory eating (*n* = 59)	Timed control (*n* = 58)	Untimed control (*n* = 50)
Age in years (*M, SD*)	27 (11)	25 (8)	25 (7)
English as a first language (%)	76	76	56
Baseline hunger (*M, SD*)	37 (27)	40 (27)	36 (28)

Manipulation check. The manipulation check data showed food attention rating means (*SD*s) of 8 (2) in the sensory eating group versus 5 (3) in the timed control group and 5 (3) in the untimed control group. An ANOVA showed a difference between conditions ($F(2, 167)$, $p < .001$, partial $\eta 2 = 0.209$). Post-hoc t-tests confirmed that significantly more attention was paid to the first cookie snack in the sensory eating condition compared to both the timed control condition, $t(115) = 6.12$, $p <.001$, $d = 1.18$ and the untimed control condition, $t(107) = 5.42$, $p <.001$, $d = 1.18$.

Effect of condition on food consumption. Table 8 reports outcome measures as a function of condition. An ANOVA (with 5,000 bootstrap resamples) showed a significant main effect of condition on total amount of food eaten, $F(2,167) = 4.38$, $p = 0.014$, partial $\eta 2 = .051$.

However, follow-up t-tests (with 5,000 bootstrap resamples) failed to show a difference in consumption between the sensory and timed control conditions, $t(115) = 0.02$, $p = .99$, $d = 0.00$, with Bayesian analysis showing substantial support for the null hypothesis, $BF_{10} = 0.197 \pm 0.03\%$. Nevertheless, as predicted, consumption was significantly lower in the sensory condition compared to the untimed control condition $t(107) = 2.65$, $p = .014$, $d = 0.47$, and in the timed control condition compared to the untimed control condition $t(106) = 2.48$, $p = .015$, $d = 0.44$.

Table 8

Mean (SD) Intake, Eating Rate and Hunger in the Sensory Eating, Timed Control and Untimed Control Conditions in Study 4

Measure	Sensory eating (n = 59)	Timed control (n = 58)	Untimed control (n = 50)
Cookie intake in grams	13 (13)	13 (14)	19 (17)
Crisps intake in grams	12 (8)	12 (9)	16 (8)
Total intake intake in grams	25 (17)	25 (20)	34 (21)
Hunger (post-manipulation)	31 (24)	31 (27)	30 (27)
Hunger (post-consumption)	24 (24)	30 (28)	26 (26)
Eating rate (bites/min)*	4.75 (1.47)	5.35 (1.80)	5.51 (1.83)

* n = 57, 51 and 43 respectively

Effect of condition on hunger. A 3(condition) x 2(time) mixed anova was used to examine differences in hunger between the three conditions immediately following consumption of the cookie pieces (post-manipulation, time 2) and immediately following consumption of the ad libitum snack (post-consumption, time 3). Hunger at baseline (time 1) was included as a covariate. As predicted, there was a significant condition by time interaction, $F(2,163) = 4.35$, $p = 0.014$, partial $\eta 2 = .051$. However, contrary to predictions, follow-up t-tests found that hunger at time 2 was not significantly higher in the untimed control condition compared to the timed control condition ($t(106) = 0.05$, $p = .958$, $d = 0.04$, $BF_{10} = 0.205 \pm 0.03\%$) or the sensory eating condition ($t(107) = 0.13$, $p = .900$, $d = 0.04$, $BF_{10} = 0.205 \pm 0.03\%$). As predicted, follow-up t-tests also showed equivalent null effects at time 3 ($t(106) = 0.89$, $p = .38$, $d = 0.15$, $BF_{10} = 0.216 \pm 0.03\%$ and $t(107) = 0.37$, $p = .71$, $d = 0.08$, $BF_{10} = 0.216 \pm 0.03\%$. Thus, in a deviation from our pre-registration we conducted additional paired t-tests exploring within-condition change in hunger from time 2 to time 3. These showed significant declines in hunger in the sensory eating condition, $t(58) = 3.58$, $p <.001$, $d = 0.29$, and the untimed control condition, $t(58) = 2.64$, $p = .01$, $d = 0.15$ but not in the timed control condition, $t(58) = 0.22$, $p = .83$, $d = 0.04$, $BF_{10} = 0.147 \pm 0.08\%$).

Effect of condition on eating rate. There were missing eating rate data for 15 participants due to recording failures. One outlier (defined as >3.5 *SD*s from the mean) was also excluded from the timed control condition leaving a total of 151 participants. Contrary to predictions, an ANOVA failed to find an effect of condition on rate of eating of the ad libitum snack, $F(2,151) = 2.96$, $p = 0.055$, partial $\eta 2 = .038$, $BF_{10} = 0.95 \pm 0.03\%$). Nevertheless, given the small-to-medium effect size in the predicted direction, we conducted post-hoc t-tests as specified in the pre-registration. In line with predictions, these showed a significantly slower rate of eating in the sensory eating condition compared to the untimed control condition ($t(98) = 2.32$, $p = .022$, $d = 0.54$) and a non-significant slower eating rate in the sensory eating condition compared to the timed condition, ($t(106) = 1.92$, $p = .057$, $d = 0.36$, $BF_{10} = 1.75 \pm 0.01\%$.

Mediation analyses (with 5,000 bootstrap resamples) showed evidence for an indirect effect of condition on intake, via eating rate when contrasting the sensory condition (coded as 1) versus the untimed condition (coded as 0), *b* = -5.02, 95% BCa CI [-9.76, -0.67], and also when contrasting the sensory condition (coded as 1) versus the timed and untimed conditions combined (coded as 0), *b* = -4.25, 95% BCa CI [-7.76, -1.00]. However, there was no evidence for mediation via eating rate when contrasting the sensory condition (coded as 1) versus the timed condition (coded as 0), *b* = -3.76, 95% BCa CI [-7.56, 0.04].

Sensory eating during the ad libitum snack. Exploratory analyses examined the extent to which participants reported paying attention to the sensory properties of the cookies during the ad libitum snack. Means were 54 (*SD* = 28), 61 (*SD* = 27) and 64 (*SD* = 26) for those in the sensory eating, timed control and untimed control conditions respectively. An ANOVA showed no significant differences $F(2,167) = 1.99$, $p = .14$, partial $\eta 2 = 0.024$, with Bayesian analysis showing weak support for the null hypothesis, $BF_{10} = 0.333 \pm 0.03\%$.

Discussion

The results of Study 4 replicated effects from Study 3, showing that those in the sensory eating and timed control conditions ate significantly less than those in the untimed control condition. These findings support the notion that effects of sensory eating on intake are driven by reductions in eating rate. However, there was no significant difference in consumption between the sensory eating and timed control condition, with Bayesian analysis showing substantial support for the null hypothesis ($BF_{10} = 0.197 \pm 0.03\%$). Thus, contrary to predictions, sensory eating did not reduce intake over and above that brought about by a slowed eating rate. We also failed to find a significant effect of condition on our primary measure of hunger, taken after the manipulation. This runs counter to the idea that slowed eating reduces intake via reductions in hunger. Nevertheless, this hunger measure may have been poorly timed since it was taken immediately following the manipulation, i.e., just over 3 minutes after onset of eating. This may have been insufficient for effects on appetite to emerge. This interpretation is supported by the main analyses that included a later measure of hunger (taken after the ad libitum snack) and which showed a significant time by condition interaction, with means that aligned with our hypotheses (despite between condition differences in quantities of snack consumed). Thus, hunger measures taken immediately prior to the ad libitum snack may have been a better assessment.

We also explored carry over effects from the sensory eating manipulation to the subsequent consumption measure. As per Study 3, we failed to find any evidence for cognitive carry over effects, in other words, we found no evidence that those in the sensory eating condition continued to pay more attention to their food after the manipulation had ended (with weak support for the null hypothesis $BF_{10} = 0.333 \pm 0.03\%$). Nevertheless, as predicted, there was some weak evidence to support behavioral carry over effects; those who had practiced sensory eating subsequently showed a slower eating rate ($d = 0.54$) compared to those in the untimed control condition. There was also evidence that eating rate mediated the effects of sensory eating on intake. However, given the pre-registered ANOVA failed to reach traditional levels of statistical significance, further research would be needed to confirm this finding.

Overall Effects

Finally, data across all four studies were combined to examine overall effects on intake and explore whether these were influenced by hunger. These analyses were first conducted on the whole sample, and then run again including only those who reported that they were not dieting to lose weight (i.e., we excluded those who reported dieting or for whom diet status data were missing). These latter analyses were considered important since people who are dieting may actively monitor and restrict their intake of food irrespective of their hunger (see Cornil & Chandon, 2016 for a similar approach). Our data showed little difference between dieters (n = 36) and non-dieters (n = 254) in terms of overall levels of hunger and intake; respectively, hunger showed means of 41 (*SD* = 27) and 40 (*SD* = 26) and intake showed means of 27 grams (*SD* = 21) and 27 grams (*SD* = 20). Nevertheless, hunger was significantly correlated with intake among non-dieters ($r = .25$, $p < .001$) but not among dieters ($r = .09$, $p = .59$).

We first used hierarchical bootstrap linear regression (with 5,000 bootstrap resamples) to compare the sensory eating condition with the control condition (irrespective of whether the latter was timed or untimed, $n = 374$). This showed a main effect of condition on intake ($b = -7.04$, $SE\ B = 2.03$, $\beta = 0.17$, $p < .001$). When hunger was entered at step 2, it significantly improved model fit ($b = 0.18$, $SE\ B = 0.04$, $\beta = 0.23$, $p < .001$), but the fit was not further improved when the interaction term was entered at step 3 ($b = -0.11$, $SE\ B = 0.08$, $\beta = -0.14$, $p = .15$). However, when the analyses were repeated[1], including only those identified as non-dieters ($n = 240$), the latter contrast became significant ($b = -0.20$, SE B = 0.09, $\beta = -0.26$, $p = .029$). Simple slopes analysis showed that when hunger was low (rated at 14, i.e., 1 SD below the mean), there was no significant effect of sensory eating on intake ($b = -3.03$, SE B = 2.96; $t = -1.02$, $p = .31$). However, at mean and high levels of hunger (i.e., when rated at 40 and 66 respectively) sensory eating led to significant reductions in the amount eaten ($b = -8.17$, SE B = 2.40; $t = -3.40$, $p = .0008$ and $b = -13.31$, SE B = 3.72; $t = -3.57$, $p = .0004$ respectively). The Johnson-Neyman method indicated that the transition point occurred when hunger was rated at 25, with all scores above this point showing a significant effect of sensory eating on intake.

The above analyses were then repeated to compare the sensory eating condition with the untimed control condition ($n = 260$). Again, results showed main effects of condition ($b = -7.29$, $SE\ B = 1.23$, $\beta = -0.35$, $p < .001$) and hunger ($b = .18$, $SE\ B = 0.05$, $\beta = 0.21$, $p < .001$) but

[1] Bootstrapping was increased to 10,000 resamples due to the bootstrap *p* value being relatively close to .05.

no interaction between condition and hunger (*b* = -0.07, *SE B* = 0.05, *β* = 0.17, *p* = .16). And again, when analyses were repeated with non-dieters only (*n* = 168), the latter contrast became significant (*b* = -0.14, SE B = 0.05, β = -0.40, *p* = .006). However, simple slopes analysis showed that sensory eating significantly reduced intake even when hunger was low (*b* = − 4.72, SE B = 1.87; *t* = − 2.52, *p* = .01), but that this effect was more pronounced when hunger was high (*b* = − 12.36, SE B = 2.12; *t* = − 5.84, *p* < .001). The transition point occurred when hunger was rated at 10.

Finally, the analyses were repeated to compare the sensory eating condition with the timed control (*n* = 267). In this case there was no effect of condition on intake (*b* = 0.44, *SE B* = 2.18, *β* = 0.001, *p* = .98). There was still a main effect of hunger (*b* = 0.16, *SE B* = 0.04, *β* = 0.23, *p* <.001) but no significant interaction (*b* = -0.11, *SE B* = 0.08, *β* = -0.29, *p* = .18). Including only those who were not dieting (*n* = 173) did not alter the pattern of results.

General Discussion

Across a series of four carefully controlled laboratory studies, we found evidence that sensory eating significantly reduces subsequent food intake. This supports previous research that has found similar effects (Allirot et al., 2018; Arch et al., 2016; Higgs & Donohoe, 2011; Mantzios et al., 2020; Robinson et al., 2014b; Seguias & Tapper, 2018). However, our results also provide an additional explanation for why some studies have failed to find effects (Cavanagh et al., 2014; Whitelock et al., 2018; 2019; Tapper & Seguias, 2020; Seguias & Tapper, 2022). Specifically, we found that, among non-dieters, effects were significantly moderated by hunger, with hungrier participants showing greater reductions in intake. Thus, where participants are not hungry, or where they are more carefully monitoring food intake due to dieting, effects may fail to emerge.

We also found evidence that the effects of sensory eating on intake might be driven by a reduced rate of eating. There is a large body of research showing how slowed eating reduces intake via effects on both physiology and psychology (Robinson et al., 2014; Hawton et al., 2019; Krop et al., 2018). In our studies, the effects of sensory eating disappeared once eating rate was controlled, and we found evidence that sensory eating did not lead to additional reductions in intake beyond that achieved by simply slowing eating rate. This explanation is consistent with the observed moderation by hunger since people who are hungry eat more quickly (Hill & McCutcheon, 1984) leaving more scope for reductions in eating rate. An important limitation of our studies is that we did not measure eating rate during the untimed sensory eating manipulation so we could not assess this as a mediator of effects. As such, it would be informative to run an additional study that simply manipulated instructions to engage in sensory eating, eat slowly or eat as normal, and to measure eating rate as well as sensory focus and subsequent food intake. Nevertheless, the weight of evidence across the four studies points strongly to slowed eating as the key mechanism of action driving the effects. Additional evidence for the effects of sensory eating on eating rate also comes from Whitelock et al., (2019) who found participants took significantly longer to eat a meal when instructed to engage in sensory eating.

By contrast, our studies suggest sensory eating does not influence intake via increased sensory specific satiety (Hetherington, Rolls & Burley, 1989; Hetherington & Havermans, 2013) or by the activation of health goals (Custers & Aarts, 2005; Papies & Aarts, 2016), since we found no differentiation of effects when comparing foods with contrasting tastes (cookies versus crisps) or health attributes (chocolate versus almonds). However, an important caveat here is that the null hypotheses and Bayesian analyses were not pre-registered but instead applied in a post-hoc manner to specific comparisons which can inflate support for the null hypothesis (Schreiner & Kunde, 2024). As such, these null effects should be interpreted with caution.

We also failed to find evidence to support mediation via the weakening of conditioned associations or by increased prioritization of sensory pleasure. Nevertheless, our measures of these latter two constructs may not have been accurate, so we cannot definitively rule them out as potential additional mechanisms of action. It is also possible that additional unidentified mechanisms of action emerge where sensory eating is employed outside the laboratory context.

Assuming effects are driven by slowed eating, it is important to identify further underpinning mechanisms. As described in the Introduction, slowed eating may promote increased orosensory exposure which has been shown to promote the release of gut hormones that reduce appetite (Hawton et al., 2019; Krop et al., 2018). In Study 4, we failed to find effects of slowed eating on measures of hunger, though it is possible our hunger measure was not sufficiently sensitive or was poorly timed. Future research could address these limitations as well as explore the possibility that slowed eating reduces hunger and craving by attenuating the blood sugar spikes and dips that occur following the consumption of carbohydrates (Wyatt et al., 2021). This may result in effects that occur over a longer timeframe, for example across the 3-hour timeframe employed in several other studies that have found significant effects (Higgs & Donohoe, 2011; Robinson, Kersbergen et al., 2014; Seguias & Tapper, 2018).

In Study 4, we found no evidence that sensory eating led to cognitive carry over effects. In other words, participants did not continue to engage in sensory eating during the subsequent ad libitum snack. However, there was some evidence for behavioural carry over effects with significant differences in ad libitum eating rate across the three conditions (mainly driven by slower eating in the sensory eating condition compared to the untimed control condition). One intriguing possibility is that slowed eating functions as a form of inhibition training, reducing automatic approach tendencies toward highly appetizing food (e.g., see Chen, Veling, Dijksterhuis & Holland, 2016; Veling, Lawrence, Chen, Koningsbruggen & Holland, 2017).

Another important area for future research would be to explore, or attempt to mimic, effects outside the laboratory. Compared to a laboratory setting, real-world environments contain a much larger array of potentially distracting stimuli, which could lead people to eat in a different way. For example, many people eat whilst engaged in other activities, such as watching TV, using a smartphone or conversing with others. As discussed in the Introduction, eating whilst distracted tends to increase intake (Robinson, Aveyard et al., 2013). As such, in addition to slowing eating rate, instructions to engage in sensory eating could help counter effects of distraction, prompting people to repeatedly return their attention to their eating, even whilst engaged in other activities (though see Hinton, Leary, Comlek, Rogers & Hamilton-Shield, 2021). This could result in larger effect sizes compared to those obtained in the current studies. Whilst it is challenging to measure real world food intake with sufficient precision to observe such effects, more laboratory research could attempt to better mimic external environments, for example by introducing environmental distractions (e.g., Ahmadyar, Robinson & Tapper, 2024).

Constraints on generality

Our studies included both male and female participants who were living in the UK but not necessarily with English as a first language. They were predominantly, but not exclusively, university students. Since the effects of sensory eating on intake appear to depend on a reduced rate of eating, we would not expect to see reductions in intake where participants' eating rate is already slow, due to a disinclination to eat, for example where they feel obliged to eat despite finding a food unappetizing or being satiated. We would also not expect to see reductions in intake where a participant is cognitively monitoring their intake to ensure they eat a certain amount. This may occur where a person is following a particular diet, living with an eating disorder, or feeling self-conscious about the amount they are eating or concerned about food waste. Similarly, we would not expect to find reductions in intake among groups of participants who already eat slowly or engage in sensory eating. We are not aware of any evidence indicating that certain cultures have higher levels of slow eating, sensory eating or cognitive monitoring of intake but cannot rule out this possibility, especially for cultures or groups with stronger traditions relating to epicurean eating, meditation or mindfulness. As such, future research would benefit from drawing on more diverse participants.

Applied implications

The findings have implications for weight management interventions. They suggest that asking people to attend to the sensory properties of their food could help them eat less. Knowing that this effect is likely mediated by rate of eating allows more precision; specifically, sensory eating should be more beneficial where people are inclined to eat more quickly, in other words, when they are hungry, in a hurry or enjoying a highly palatable food (Hill & McCutcheon, 1984). Additionally, sensory eating may be more beneficial for those who are naturally fast eaters. Evidence suggests fast eating has a hereditary component with fast eaters having higher BMIs (Llewellyn, Van Jaarsveld, Boniface, Carnell & Wardle, 2008; McCrickerd & Forde (2017); Ohkuma et al., 2015). Future research could usefully explore the relative benefits of sensory eating for fast versus slow eaters to confirm this line of reasoning.

Although there were not sufficient dieters within our sample to examine moderation of effects by dieting status, the findings suggest that effects could differ for this sub-group, given that (in contrast to non-dieters) hunger was not correlated with intake. At face value, this might imply that sensory eating would not be beneficial for those attempting to lose weight. However, there is increasing recognition of the need for weight management programmes to foster strategies that can be maintained over the long term, to help avoid the weight regain that typically occurs following weight loss interventions (Dombrowski, Knittle, Avenell, Araújo-Soares & Sniehotta, 2010). With this in mind, there have been calls for weight management programmes to place more emphasis on helping people learn to better recognise and respond to bodily cues (Schaefer & Magnuson, 2014). Sensory eating could be an important part of such an approach.

One potential criticism of sensory eating is that, given mediation by slowed eating, it may be more straightforward to simply advise people to slow their eating. However, despite the apparent simplicity of such advice, high levels of automaticity in many eating contexts (e.g., Neal, Wood, Wu & Kurlander, 2011) mean such an approach can be hard to implement. Researchers have tried to address this with a range of different strategies such as recommending participants chew each bite of food a certain number of times, place down their cutlery between each bite, or use technology (such as smart cutlery) to alert them when they are eating too fast (e.g., Hermans et al., 2017). However, the success of such strategies may be limited by acceptability and adherence, especially where participants report reduced food enjoyment (Cox et al., 2002; Ferriday et al., 2016; Hawton et al., 2018; though see also Venegas, Farfa Beltrán, Bucchi, Martínez Gomis & Fuentes, 2022). By contrast, there is evidence to suggest that sensory eating may increase food enjoyment (Seguias & Tapper, 2022). As such, sensory eating may be a more acceptable strategy that is easier to maintain. Helping people to remember to engage in sensory eating is an additional challenge but this might be achieved using action planning techniques such as implementation intentions (Gollwitzer & Sheeran, 2006). For example, future research could explore the combination of sensory eating and implementation intentions with those who are both naturally fast eaters and motivated to manage their weight. If continued for a sufficient length of time, sensory eating could become a habitual response to eating that might then be sustained over time with minimal effort (Lally & Gardner, 2013).

However, it is important to acknowledge that effects may differ outside the laboratory context. In particular, they may be unlikely to emerge where people eat pre-portioned foods, such as a shop-bought sandwich or bag of crisps, or where food is portioned and served by someone else. This is because serving size is a highly salient cue used by people to guide portion size, i.e. the amount they eat (Fay et al., 2011). An aversion to wasting food could also be a more important influence on intake in such settings (Cleobury & Tapper, 2014). Additionally, one could argue that reduced consumption as a result of sensory eating may be compensated for by increased consumption at a later point in time. However, even if this did occur, evidence suggests it is unlikely to be full compensation (Robinson, McFarland-Lesser, Patel & Jones, 2023). In other words, there would still likely be an overall reduction in daily calorie intake. As noted above, testing effects outside the laboratory is challenging given reductions in intake are likely to be too small to be picked up by self-report dietary measures. For example, our overall analysis showed a reduction in intake of just 7 grams, equivalent to around 38 kcal of a high calorie food such as chocolate or crisps. Effects may be larger across an entire day. Nevertheless, the only reliable way of examining the effects of sensory eating on intake outside the laboratory is likely to be by assessing weight change over a longer period of time. An additional challenge here would be ensuring long term strategy adherence.

Toward a theoretical understanding of mindfulness

The four experiments described in this paper demonstrate the value of dismantling mindfulness practice to identify underpinning mechanisms of action. Some might argue that the sensory eating practice we examined is not a good reflection of either mindfulness or mindful eating since it draws on just one feature of mindfulness practice (present moment awareness) whilst neglecting others (e.g., an attitude of acceptance; meta-cognitive awareness). It is possible that unique benefits of mindfulness emerge only through the combination of these features (e.g., see Lindsay & Creswell, 2019). Likewise, it is possible that unique benefits of mindful eating only emerge when these features are employed in combination across a wide range of different eating related contexts (for example, in response to urges to eat and when making food choices as well as when actually eating). However, only by comparing the effects of practices in isolation versus combination will we be able to reach such conclusions and develop theory that can help us more effectively use mindfulness in applied settings. In addition to these theoretical concerns, there may also be more direct real-world value in examining practices in isolation. Traditional approaches toward cultivating mindfulness tend to be both lengthy and effortful (Tapper, 2022) which may limit its appeal and accessibility for large numbers of people. Identifying short, discrete practices associated with specific effects could help widen uptake and increase adherence (as well as cost-effectiveness). The more immediate benefits provided by such practices could also help maintain motivation and potentially function as a gateway for experimentation with other mindfulness practices.

Author contributions statement

Lana Seguias: conceptualisation; methodology; investigation (lead); data curation (lead); formal analysis; writing - original draft. Elanor Hinton: conceptualisation; methodology; data curation; formal analysis; writing - original draft; writing - review and analysis. Danielle Ferriday: conceptualisation; supervision; methodology; formal analysis; writing - review and editing. Tina McCraw: investigation; data curation; formal analysis. Katy Tapper: conceptualisation (lead); supervision; methodology; formal analysis; writing - original draft (lead); writing - review and editing.

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Appendix 1. Scripts for audio recordings used in Study 1

Sensory eating condition

You will be given a cookie to eat. While eating the cookie, try to think about its sensory properties. Focus on its look, feel, smell, taste, texture, and sound.

Imagine that you are seeing the cookie for the first time. Hold it in your palm between your fingers and thumb and examine it. Look at its colour and the way this colour varies. Feel its texture between your fingers. Focus on its weight and temperature. Notice its smell. Does the cookie have a smell? Take in its odor, whatever it is, if there is one.

As you start to bite into the cookie, slowly roll it over your lower gums and then the upper gums as you feel its shape, texture, and temperature. When you begin to chew, feel its every aspect. Notice the bare sensations of taste and texture in the mouth and how these may change over time, moment by moment. Is the texture hard or soft? Crispy or chewy?

Also, notice the sound you make as you chew. Is the sound loud or quiet? Sharp or muffled? Finally, feel the bursting of flavor and work the cookie toward the back of the throat and swallow it, observing its path as it traverses the throat and finally enters the stomach.

Control condition

You will be given a cookie to eat. Cookies are made by first combining dry ingredients like flour, baking soda, and salt together in a medium sized bowl. Then in a larger bowl ingredients like butter, white sugar, brown sugar, and vanilla are combined and mixed together with eggs until perfectly blended. After this, the dry ingredients from the medium bowl are mixed together with the ingredients in the big bowl. Eventually, all the ingredients are perfectly mixed. At this point, one would have fairly thick cookie dough, whereby chocolate chips could be added.

Following this, medium sized scoops of cookie dough should be taken on a spoon and dropped on a cookie sheet. The scoop is then flattened. One should make sure there is at least an inch of space between the cookies in order to bake properly.

Finally, the oven should be pre-heated to 350 degrees and the cookies should be baked for about eight minutes. The cookies should then be removed from the oven. It is best to let the cookies sit in the pan for about 5 minutes. Then, using a spatula the cookies can be lifted off the cookie sheet and can be eaten.

Appendix 2. Script for the audio recording used in the sensory eating conditions in Studies 2, 3 and 4

While eating the cookie, try to focus on its look, feel, smell, taste, texture, and sound.

Look at the colour of the cookie and the way the colour varies.

Notice the smell of the cookie.

As you bite into the cookie, feel its shape, texture, and temperature.

Does the cookie feel cool in your mouth or warm?

Notice the texture of the cookie. Is it hard or soft?

How does the texture of the cookie change as you chew?

Notice the sound you make as you chew. Is it loud or quiet? Sharp or muffled?

Think about the flavor of the cookie. Is it mild or strong?

Does the flavor change as you chew?

Does the cookie taste different in different parts of your mouth?

What sorts of flavours can you detect in the cookie?