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Imagine this: Visualising a recent meal as bigger reduces subsequent snack intake

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ABSTRACT

Remembering a recent meal reduces subsequent intake of palatable snacks (i.e. the meal-recall effect), however, little is known about the factors which can potentiate this effect. The present experiment investigated whether a stronger meal-recall effect would be observed if recent consumption would be recalled in greater detail, than if it was recalled briefly. Moreover, it was investigated whether imagining a meal as bigger and more satiating than in reality could potentiate the meal-recall effect, and lead to lower intake. It was also explored whether mental visualisation tasks of a recent meal would affect the remembered portion size. Participants (N = 151) ate lunch at the laboratory, and then returned 3 h later to perform the imagination tasks and to participate in a bogus taste test (during which intake was covertly measured). Participants in the two main imagination task groups recalled the lunch meal and then either recalled the consumption episode in great detail or imagined the meal was larger and more filling than in reality. The results showed that imagining a recent meal as larger significantly reduced the quantity of biscuits eaten. However, contrary to the hypotheses, recalling a consumption episode in detail did not decrease snack intake. It was also shown that imagining a recent meal as larger than in reality did not lead participants to overestimate the true size of the meal. In fact, portion size estimations were significantly underestimated in that group. There were no significant estimation differences in any of the other groups. The results of this study suggest that the meal-recall effect can be an effective strategy to reduce food intake and may be amenable to strategic manipulation to enhance efficacy, but seems prone to disruption.

1. Introduction

Eating behaviour is regulated by a variety of complex mechanisms (Dovey, 2010). Signals from, and interactions between, organs, hormones, tissues and neurotransmitters help to encourage intake when energy resources are depleted, and to terminate a meal once a sufficient amount of energy is ingested (Crowley, 2008). However, it is being increasingly recognised that appetite is not only regulated by such physiological cues, but also by a multitude of cognitive factors (Higgs, 2008; Higgs & Spetter, 2018). Of particular interest is the finding that memories of recently consumed meals can modulate subsequent intake.

1.1. The meal-recall effect

The meal-recall effect is a strong example of how memory can influence eating behaviour. In one experiment (Higgs, 2002), asked participants to recall either a recently consumed meal, or a meal consumed the previous day. Participants were then given the opportunity to snack on some sweet biscuits (cookies), during an ostensible taste test. It was reported that participants who recalled a recently consumed meal ate fewer biscuits than those who recalled a meal from the previous day. This phenomenon has been termed 'the meal-recall effect' (Szypula, Ahern, & Cheke, 2020).

Higgs, Williamson, and Attwood (2008) replicated the meal-recall effect in three experiments, demonstrating that: a) the effect can be elicited with other food types (in this case popcorn), b) that it is most prominent in participants scoring low on disinhibition, and c) that it does not occur if the delay between the meal and the recall is brief. Collins and Stafford (2015) replicated the meal-recall effect and showed that it was disrupted when a positive mood was induced in participants. The researchers hypothesised this was due to positive mood decreasing attentional resources, thereby weakening the inhibitory effect of recent meal recall. Vartanian, Chen, Reily, and Castel (2016) reported a 40% decrease in intake between those who recalled a recent meal, and those

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who recalled a non-food event, further adding to the idea that recent meal recall modulates consumption. Our lab was also able to demonstrate this effect, but we found no evidence to suggest that dietary disinhibition modulated its magnitude (Szypula et al., 2020). Furthermore, we observed that the manifestation of the effect was disrupted by elaborating on the meal memory (vs. when no further details of the memory were requested), and that general episodic memory ability did not play a significant role in the effect. We further found that the effect was elicited if the mode of recall was written, but not if it was verbal. Interestingly, Yeomans, Milton, and Chambers (2017) found that recalling a recently consumed drink (vs. recalling a drink consumed the previous day) also led to lower subsequent intake of a beverage, perhaps suggesting that the meal-recall effect is not specific to a particular type of sustenance. More recently, Arthur, Stevenson, and Francis (2021) showed that recalling a recent meal (vs. a distant meal) affected ratings of prospective intake too, and the authors suggested the meal-recall effect may thus be underpinned by conscious effort to restrict intake. In a recent (unpublished) study, we were also able to show that recalling recent meals (vs. non-food events) leads to lower prospective intake of biscuits (cookies), but we did not observe a moderation of dietary restraint on the magnitude of the effect (Szypula, 2021).

In light of these findings, it seems that recalling a recent meal can modulate subsequent intake, but it is also evident that the effect is prone to disruption by contextual factors. Inducing a positive mood in participants (Collins & Stafford, 2015), recalling a meal which is too recent (Higgs, Williamson, & Attwood, 2008), asking participants to recall their meal in detail (e.g. by describing the textures and flavours, where the meal was eaten, who it was eaten with etc.; Szypula et al., 2020), or asking them to verbally recall the meal memory (Szypula et al., 2020) are all factors which can disrupt the meal-recall effect and prevent it from manifesting. At present, it is not clear why such seemingly small changes can have such detrimental effects on whether or not recent meal recall suppresses subsequent intake. However, one idea we explored in our earlier study (Szypula et al., 2020) was that in order for the meal-recall effect to be elicited, an individual must recall the *act* of having eaten the meal, rather than simply thinking about the food, or about food in general. We found that when participants were prompted for details about their recent meal, their snack intake *increased*, relative to those who were not asked to elaborate on their recollections. We speculated this might have been because participants prompted for details focussed on the food itself (prompting hunger), rather than on the consumption episode (prompting satiety), which led to an increase in intake (Fedoroff, Polivy, & Herman, 1997). Thus, the present experiment aimed to test the hypothesis that a stronger meal-recall effect would be observed if the prompts were focussed on the details related to the action of eating the meal (rather than details about the food eaten).

1.2. Manipulating meal memories

Another aim of the present experiment was to assess how manipulating the details of a recent meal memory could impact subsequent intake. Specifically, we aimed to test whether imagining a recent meal as bigger and more satiating than in reality would decrease subsequent biscuit consumption. People often under- or overestimate their food intake (Rolls, Morris, & Roe, 2002), and the actual amount of food consumed does not always match subsequent satiety (Brunstrom et al., 2012), and so we expected recent meal memories to be susceptible to interference from the imagination task. Previous studies have demonstrated that what individuals remember about a meal can affect their appetite. For instance, Brunstrom et al. (2012) showed people a bowl containing either 300 ml or 500 ml of soup. The participants then ate from this self-filling/self-draining bowl and either ingested the amount of soup they were presented with or ingested an amount different to the one witnessed (i.e. intake could be 'congruent' e.g. see 300 ml, eat 300 ml or 'incongruent' e.g. see 300 ml, eat 500 ml). The results showed that over the inter-meal interval, hunger increased to a lesser extent in those who saw a 500 ml bowl of soup, irrespective of whether they actually consumed 300 ml or 500 ml. In other words, 2 h after the meal, hunger was predicted by remembered consumption, rather than by actual consumption.

Thus, we hypothesised that if people are asked to imagine their meal was bigger than in reality, this could affect their appetite and lead to a decrease in subsequent snacking. This logic was supported by findings of a virtual reality study, in which participants were asked to eat some biscuits whilst wearing a headset (Narumi, Ban, Kajinami, Tanikawa, & Hirose, 2012). Unbeknownst to the participants, the researchers altered the size of the biscuits the participants were eating, so that they appeared smaller or larger than in reality. It was found that when the biscuits appeared to be larger than in reality, intake was suppressed, relative to intake when the biscuits appeared smaller than in reality or when their size was not manipulated (Narumi et al., 2012). This demonstrates that intake can be modulated by visual cues, even if these cues do not correspond to actual intake.

To date, few experiments have focussed on establishing the factors which can strengthen the meal-recall effect. Previous research has observed a substantial reduction in intake following recent meal recall (17.6g; Szypula, 2021), but inter-study variation is significant. The meal-recall effect has been shown to reduce subsequent intake anywhere from 14.5% to 53.6%, and it is not clear what drives this discrepancy (Szypula, 2021). Investigating factors which could potentially amplify the meal-recall effect could help to understand how best to utilise it for weight loss and weight management and could help to elucidate what the mechanism behind the effect might be.

1.3. Mental simulation and its effects

Mental simulation of events can sometimes act as a substitute for experience and have consequences on overt behaviour (Kappes & Morewedge, 2016). For instance, mental visualisation of physical practice (e.g. playing the piano) can increase subsequent performance (Driskell, Copper, & Moran, 1994), and imagining the performance of certain events (e.g. donating blood) can increase intentions to actually partake in the imagined experience (Anderson, 1983). Moreover, visualising repeated consumption of sweets can elicit sensory-specific satiety, which can in turn decrease actual consumption (Morewedge, Huh, & Vosgerau, 2010). This implies mental simulation of consumption can elicit real effects on behaviour and cognition.

It is well established that episodic memories are prone to distortion (Schacter, Guerin, & St. Jacques, 2011). Being exposed to contradicting information after an event can change an encoded memory (Loftus, Miller, & Burns, 1978), and in some cases engaging with new, incorrect information can generate false memories (Loftus & Pickrell, 1995; Nash, Wade, & Lindsay, 2009). There is also evidence to suggest that sometimes exposure to incorrect post-event information can result in information 'blending' – for example, participants report having seen a blue-green car after seeing a green car and later being told it was blue (Loftus, 1977). Meal memories are not immune to the influence of post-event misinformation. In fact, they may be particularly prone to interference (Wixted, 2004) due to the habitual and repetitive nature of mealtimes (White & McDonald, 2002), which means individual eating episodes are rarely distinctive.

It has been demonstrated that imagination can have rapid and profound consequences on the accuracy of memories. Weinstein and Shanks (2010) showed participants photographs, which were either in colour or black and white. Participants were then shown the names of the items in the photographs they just saw and were asked to recall whether a particular item was presented in colour or in black and white. At this point, novel, previously unseen items were included in the identification task. The researchers instructed the participants to imagine what an item might have looked like, if they could not recall seeing a photograph of it. Then, at the final test, participants were shown the old photographs they initially memorised, as well as photographs of items they were asked to imagine. The results revealed that participants falsely recalled seeing the imagined items 29% of the time, suggesting that merely visualising an event can produce false memories.

Following this logic, we hypothesised that imagining a previous meal as larger would elicit a post-event misinformation effect, and that merely visualising the portion as bigger could lead participants to overestimate the true portion of the baseline meal. There are a number of ways to gauge the size of a remembered meal size, for example through photograph selection. In a study by Nelson, Atkinson, and Darbyshire (1996), participants first served themselves a portion of food, and 5 min later selected a photograph which most accurately reflected the size of the meal they ate. It was shown that lean participants (with a BMI less than 25) showed a 5–10% overestimation for most food types, whereas participants with obesity (with a BMI over 30) showed a 2–5% portion underestimation. De Keyzer et al. (2011) also found that food photographs were a reasonable method of estimating portions (r ranged from 0.48 to 0.75), but the researchers only used bread, margarine, coffee and water as the test foods. However, estimation accuracy can be influenced by the stimuli used (e.g. minimum and maximum portion sizes shown in the photographs; Faggiano et al., 1992), and best results are obtained when a large number of photographs (approximately 50) are used (Wilkinson et al., 2012).

An alternative method of assessing the consumed portion size is physical recreation of the past meal with food replicas or models (Amoutzopoulos et al., 2020; Murkin et al., 2003). Although this method is not used as frequently as photographs (Amoutzopoulos et al., 2020) it may potentially provide a more accurate reflection of remembered portion size, than relying on selection from pre-specified portions. Thus, in the present experiment, participants were given a fixed meal at the laboratory, and then physically re-created the remembered size of their meal. It was predicted that those who imagined their previous meal as larger than in reality would overestimate the true portion size of the reference meal.

1.4. The role of restraint

Arthur et al. (2021) replicated the meal-recall effect online (using food photographs as a proxy for intake) and argued that the mechanism for the effect was related to dietary restraint. The authors proposed that recalling a recent meal acts much like high dietary restraint, in that it causes individuals to consciously restrict their intake, irrespective of whether or not they are hungry. To support this hypothesis, the authors conducted a moderation analysis, which revealed that in the control group dietary restraint predicted intake (higher restraint was related to lower intake), but in the experimental group this association did not exist (because all participants restricted their intake, as though they all scored high on restraint). This mechanism does not align with previously reported findings. In her early studies, Higgs only recruited participants who scored low on dietary restraint (Higgs, 2002), but in 2008 showed that the meal-recall effect was not affected by low (DEBQ score <2.3) or high levels of dietary restraint (Higgs, Williamson, & Attwood, 2008). Moreover, in our previous experiment (Szypula et al., 2020) we recruited a diverse sample of participants and found no evidence to suggest that the meal-recall effect was modulated by dietary restraint. Similarly, no effect of restraint has been found in our other (yet unpublished) studies (Szypula, 2021). To help clarify the role of restraint in the meal-recall effect, it will be included in the analysis of the present experimental findings, but it is expected restraint will not modulate the meal-recall effect.

1.5. Overview of research aims

Taken together, these findings suggest that simply thinking that one ate more than in reality can decrease subsequent hunger and intake, mental simulation can affect overt behaviour, and that imagining events can alter original memories. The present experiment investigated whether asking people to visualise having eaten a larger meal than in reality would decrease the amount of biscuits they subsequently ate. Following previous evidence that recalling a recent meal tends to decrease subsequent snacking (Higgs, 2002), it was investigated whether imagining a that recent meal was bigger than in reality would further suppress snack intake relative to simple recall. The study also explored how this mental simulation task would affect the original memory of the meal.

Briefly, the experiment involved participants attending a laboratory session, during which they were served a fixed portion of food. Participants returned 3 h later and listened to an audio recording of a visualisation task. Participants were asked to close their eyes, listen to the clip, and to form a mental image of the events being described. Each participant was randomly assigned to one of five visualisation conditions: the Recall + Enlargement group recalled their most recent meal, and imagined their meal was bigger and more filling than in reality. The Recall + Rumination group also recalled a recent meal, and visualised its consumption in great detail. The remaining conditions were control groups: the Recall + Handling group recalled a recent meal and imagined moving it around the plate. The Food Picture + Handling group, and the Non-Food Picture + Handling group were not asked to remember their recent meal at all. Instead, they were shown a photograph (of novel food, or of some stationery), and were asked to describe it. Then, they visualised moving the novel food or the stationery around the plate during the audio clip. It was hypothesised that recalling an eating episode in great detail in the Recall + Rumination group would decrease snacking, relative to the control groups, and it was predicted that imagining a recent meal as bigger in the Recall + Enlargement group would suppress intake even more. It was also anticipated that imagining a meal as larger would lead to overestimation of the true portion size, as evidenced by performance on the physical portion estimation task.

2. Method

2.1. Ethical approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

2.2. A Priori power analysis

Szypula et al. (2020) found a large meal-recall effect size Cohen's d_z $= 0.62$ when a within-subjects design was employed. However, to account for the fact that part of the present study investigates a novel idea, and for the fact that the design of this study is between-subjects, the power analysis was set to detect a medium effect size instead (Cohen's f $= 0.30$). The power analysis was conducted in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007). In order to achieve 80% power to detect a medium effect size, a minimum of 140 participants were required ($n = 28$ for each of the five experimental groups).

2.3. Participants

Participants were recruited from the University of Cambridge participant pool and newsletter announcements, and 156 individuals participated in the study. The inclusion criteria were: 18–65 years old, willing to eat the food provided in the study, willing to fast for 3 h between sessions 1 and 2, no history of eating disorders and fluent English speakers. Participants were also excluded if they were allergic to any of the foods provided.

2.4. Design

A between-subject design was used. Participants were randomly allocated to one of five conditions (see Table 1). All participants ate a

Table 1
Summary of the tasks participants were asked to perform in the five different conditions employed in the experiment.

Condition	Pre-imagination task	Imagination exercise contents
Recall + Handling	Recall recent lunch	Imagine moving recent lunch around the plate
Recall + Rumination	Recall recent lunch	Recall eating recent lunch in detail
Recall + Enlargement	Recall recent lunch	Imagine recent lunch was twice as big
Food Picture + Handling	Describe a new meal shown on a photograph	Imagine moving a new meal around the plate
Non-Food Picture + Handling	Describe stationery shown on a photograph	Imagine moving stationery around the plate

lab-provided lunch and then 3 h later returned to the lab to complete an imagination exercise and a bogus taste test of biscuits. Imagination exercise type was the independent variable ('Recall + Handling' vs. 'Recall + Rumination' vs. 'Recall + Enlargement' vs. 'Food Picture + Handling' vs. 'Non-Food Picture + Handling'). Total biscuit intake (g) during the taste test was the dependent variable.

2.5. Materials

2.5.1. The lunch meal

Participants were served a 300g pot of Uncle Ben's™ Rice Time Sweet and Sour (338 kcal per portion; 113 kcal per 100g). The meal was heated in a microwave for 90 s and then served on a single-use plastic plate with a plastic fork. The rice was put in the middle of the plate and the sauce was poured on top of it. A 250 ml cup of water was also provided. Participants were instructed to eat the whole meal if they could but were asked to not make themselves feel uncomfortable.

2.5.2. Questionnaires

Participants rated their mood using a questionnaire presented in Qualtrics. Participants rated their mood on ten different aspects (thirst, hunger, tiredness, stress, happiness, relaxation, bloating, nervousness, excitement, irritability) on a slider scale which ranged from 0 (not at all) to 10 (extremely). The questionnaire was used as a way of measuring hunger levels, without indicating to the participants that this variable was of a particular interest to the experimenter. The mood questionnaire also served to strengthen the plausibility of the ostensible aim of the experiment (understanding how mood affects taste).

Participants also completed the Restraint subscale of the Dutch Eating Behavior Questionnaire (van Strien, Frijters, Bergers, & Defares, 1986) and the Disinhibition subscale of the Three Factor Eating Questionnaire (Stunkard & Messick, 1985). Both questionnaires were presented using Qualtrics and completed on a computer.

2.5.3. Meal-recall and imagination exercises

For the pre-imagination task, participants in all of the 'Recall +' conditions were instructed to remember what they ate for the lab-based lunch (Uncle Bens™ Rice) and were asked to type their recollection into a textbox presented on a computer screen. The instructions reminded participants to be specific about the ingredients and their amounts when describing their lunch. Participants in the remaining 'Food Picture + Handling' and 'Non-Food Picture + Handling' conditions were not asked to remember their lunch. Instead, they were shown a photograph depicting either 400g of Heinz™ Spaghetti Hoops in tomato sauce ('Food Picture + Handling'), or a handful of paperclips and rubber bands ('Non-Food Picture + Handling') arranged on a plate. Participants were instructed to examine the photograph carefully for as long as they wanted, and they were then asked to write a short description of the contents of the photograph they had seen.

For the imagination exercises, all participants listened to a guided imagination exercise over headphones. The content was different in each condition (see Table 1). The imagination exercises were matched as closely as possible on their duration and the number of words they contained ('Recall + Handling': 189 words, 1:55 min; 'Recall + Rumination': 188 words, 1:51 min; 'Recall + Enlargement': 185 words, 1:58 min; 'Food Picture + Handling': 194 words, 1:44 min; 'Non-Food Picture + Handling': 194 words, 1:52min). The average exercise length was 1:52 min. Each imagination exercise contained five breaks which were 7 s long and one 15-s break, during which participants could perform the mental manipulations (see supplementary materials). The voice used to record the imagination exercises belonged to an adult female, who was not the experimenter.

2.5.4. Bogus taste test

The procedure for the bogus taste test was based on Higgs (2002). Three boxes containing approximately 100g of biscuits were put in front of the participant. The biscuits were presented in a fixed spatial arrangement of Milk Chocolate Fingers (Cadbury, 516 kcal per 100g), Digestives (McVities, 495 kcal per 100g) and Chocolate Chip Cookies (Maryland, 487 kcal per 100g). A 250 ml cup of water was also provided. During the bogus taste test, participants rated three types of biscuits on twelve different taste attributes (e.g. how crunchy, chocolatey, salty etc. they were). Ratings were made on a slider scale from 0 to 100, on an online questionnaire designed in Qualtrics. The ratings were made for one type of biscuits at a time in a fixed order (Cadbury Fingers, McVities Digestives, Maryland Cookie). The taste-rating task was explained to the participants, who were also informed that they were free to eat as many biscuits as they wished, since the biscuits would have to be disposed of at the end of the session for hygiene reasons. Lastly, the participants were asked to report whether there was anything that could have influenced the amount of biscuits they ate (e.g. illness, stress). These reasons were assessed at the end of data collection and none of them were deemed significant enough to justify exclusion from the analyses.

2.5.5. Physical portion estimation

Participants were asked to physically recreate the portion of food they received, in order to assess their memory for the original size of the lunch meal. They were given two containers, one with 500g of rice and one with 500g of sweet and sour sauce. They were also provided with a clean plate and a clean bowl and were asked to put the amount of food they remembered having onto the plate and into the bowl. Participants were asked to put the rice and the sauce into separate containers when performing the size estimation. This was done for practical reasons, as unmixed food could have been re-used by other participants which minimised food waste.

2.6. Procedure

Before coming to the experimental session, participants were asked to fast for at least one and a half hours, to ensure that they would be able to eat the lunch provided. Participants were asked to confirm that they were not allergic to any of the ingredients and were asked how many hours ago they last ate. They then completed a demographics questionnaire (age, sex, weight, height) and were given the lunch meal. Participants were asked to try and eat the whole portion if they could, but to not force themselves or make themselves feel uncomfortable. The experimenter then left the room and waited for the participant to call her back once they finished eating. After eating, participants completed another mood questionnaire, along with TFEQ and DEBQ. Completion of these questionnaires marked the end of the first session and participants were asked to come back 3 h later. They were also reminded to refrain from eating or drinking anything with calories in it over this period of time.

The second session began 3 h later with completion of the mood questionnaire. Then participants completed the pre-imagination task (either recall or picture, depending on the condition they were in - see

Table 1). They were then instructed to close their eyes and listened to the imagination exercise through headphones (again, the specific exercise depended on condition). Next, participants were asked to complete the mood questionnaire and to rate how immersive, real, detailed, and believable the events imagined during the listening tasks were, and how easy it was to imagine them.

Afterwards, participants completed the biscuit taste test. The experimenter then answered any questions the participants might have had and left the room for 10 min. Once the time was up, the experimenter returned to the room and asked the participants to perform a physical portion estimation, during which they re-created the portion of food they received with real food. Lastly, participants were fully debriefed and given the chance to ask any questions. They were paid £10 for their participation.

3. Results

3.1. Initial analyses

3.1.1. Participant exclusion

Altogether, 156 participants were recruited for the study. Data from five participants were excluded. A manipulation check revealed that when asked to recall their lunch (rice and sauce), three participants failed to follow instructions and recalled different food items. This also suggests they did not refrain from eating between the two sessions, and so these cases were removed from the analysis. One participant guessed the aim of the study, as she previously took part in a biscuit taste test in a different experiment, and so was removed from the analysis. One participant made it clear that he would attempt to eat all of the biscuits provided, and so his data was also excluded.

3.1.2. Checking statistical assumptions

Firstly, it was assessed whether the total weight of biscuits consumed was normally distributed. The skewness value (across all conditions) was 1.14 ($SE = 0.197$) and kurtosis was 1.56 ($SE = 0.392$), revealing a positive skew of the data. The variable was square-root transformed, and this reduced the skewness value to 0.40 ($SE = 0.197$) and kurtosis to 0.18 ($SE = 0.392$). The homogeneity of variance assumption was met, as shown by a non-significant Levene's test, $F(4,146) = 0.74$, $p = .565$.

3.2. Participant demographics

Data from 151 participants was used in the analysis (104 female, 68.9%). Participants' ages ranged from 18 to 57 ($M = 25.07$, $SD = 7.78$), and BMI scores ranged from 17.16 to 35.83 ($M = 22.39$, $SD = 3.30$). The five experimental groups were mostly similar on their baseline characteristic (see Table 2).

3.3. Post-meal analyses

As expected, a repeated-measures ANOVA revealed that hunger rating significantly decreased between the pre-lunch and post-lunch timepoints, $F(1,146) = 515.81$, $p < .001$, $\eta_p^2 = 0.779$, and the interaction with condition was not significant, $F(4,146) = 1.29$, $p = .279$. Although participants were instructed to finish the entire meal, 19.9% (n = 30) of the sample did not eat the whole portion provided. On average, 17.62g of lunch was left ($SD = 39.96$). The proportion of participants who did not eat the entire meal, and the weight of the leftover food, did not differ between the groups (see Table 3). Excluding participants who did not finish their lunch did not change the results of the main analysis.

3.4. Imagination exercises

A repeated-measures ANOVA assessing pre-to post-imagination task changes in hunger indicated that there were no significant differences, $F(1,146) = 0.13$, $p = .721$. However, the interaction term was significant, $F(4,146) = 5.55$, $p < .001$, $\eta_p^2 = 0.132$. Post-hoc paired-samples *t*-tests revealed that there was a significant pre-to post-visualisation task decrease in hunger ratings in the Recall + Enlargement group, $t(30) = 3.55$, $p = .001$, Cohen's $d_z = 0.64$. No other comparisons were significant (all $p > .05$). The Recall + Enlargement exercise was rated as least immersive, real or detailed, as well as most difficult to visualise, however one-way ANOVAs revealed that these differences in ratings were not significant (see Table 4).

3.5. Effect of visualisation on biscuit consumption (main analysis)

A one-way ANOVA was conducted, with total biscuit intake (transformed) as the dependent variable and the experimental condition as the independent variable. Overall, the model was significant, suggesting that biscuit intake varied depending on the imagination exercise, $F(4,146) = 2.88$, $p = .025$, $\eta_p^2 = 0.073$[1] (see Table 5 and Fig. 1). Next, eight planned comparisons were performed.

The first comparison explored whether the meal-recall effect was elicited in the meal-recall groups ('Recall + Handling', 'Recall + Rumination' and 'Recall + Enlargement') relative to the control 'Non-Food Picture + Handling' group. Only the 'Recall + Enlargement' group ate significantly fewer biscuits than the 'Non-Food Picture + Handling' group, ($p = .004$; Cohen's $d = 0.82$ [large]). Neither the 'Recall + Handling' group, nor the 'Recall + Rumination' group, differed significantly from the 'Non-Food Picture + Handling' group in terms of total biscuits eaten, ($p = .690$ and $p = .463$, respectively).

The next set of comparisons explored how 'Recall + Enlargement' influenced biscuit consumption, relative to other manipulations following recent meal recall. Imagining the portion as bigger in the 'Recall + Enlargement' condition decreased the amount of biscuits consumed, relative to imagining moving the food around the plate in the 'Recall + Handling' condition, ($p = .014$; Cohen's $d = 0.67$ [medium]). The 'Recall + Enlargement' group also ate fewer biscuits than those in the 'Recall + Rumination' condition ($p = .033$, Cohen's $d = 0.58$ [medium]). However, the difference between the 'Recall + Rumination' and 'Recall + Handling' conditions in the total amount of biscuits eaten was not significant, ($p = .737$).

To investigate whether thinking about food in general (rather than about a specific consumption episode) influenced snacking behaviour, the 'Food Picture + Handling' and the 'Non-Food Picture + Handling' conditions were compared in terms of the amount of biscuits consumed. No significant differences were observed ($p = .936$). It was also assessed whether imagined handling of a new meal in the 'Food Picture + Handling' group would increase snacking, relative to imagined handling of a recent meal in the 'Recall + Handling' group, but no significant differences were found, ($p = .750$).

No hypotheses were put forward for the remaining comparisons, and so they were conducted *post-hoc* using Tukey's HSD test. The difference between the amount of biscuits consumed between the 'Recall + Enlargement' and 'Food Picture + Handling' groups was significant ($p = .043$, Cohen's $d = 0.15$ [small]). However, the difference in consumption between the 'Recall + Rumination' group and the Food Picture + Handling' group was not ($p = .965$).

3.6. Bayesian test

In light of the fact the meal-recall effect was not replicated in the 'Recall + Rumination' group (see section 3.5), a Bayesian ANOVA was conducted using JASP (JASP Team, 2022; van den Bergh et al., 2020), with default priors (Cauchy scale). The omnibus analysis returned a BF10 of 1.49, providing weak evidence in favour of the alternative

[1] The analysis remained significant when no participants were excluded, $F(4,151) = 3.31$, $p = .012$, $\eta_p^2 = 0.081$.

Table 2
Comparison of participant baseline characteristics, in the different experimental conditions.

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
N	30	30	31	30	30	
Sex (M/F)	7/23	11/19	8/23	8/22	13/17	$\chi 2$ (4) = 4.05, p = .399
Age	25.43 (6.65)	25.30 (9.78)	23.35 (4.69)	26.97 (10.15)	24.37 (6.34)	F(4,146) = 0.90, p = .464
Age range	19–52	18–57	18–38	18–57	18–51	
BMI	22.23 (2.99)	22.93 (4.87)	23.01 (2.91)	22.41 (2.97)	21.32 (2.05)	F(4,146) = 1.29, p = .318
Restraint (DEBQ)	2.45 (0.93)	2.59 (0.92)	2.07 (0.81)	2.31 (1.07)	2.45 (0.84)	F(4,146) = 1.40, p = .239
Disinhibition (TFEQ)	7.53 (3.54)	7.47 (3.44)	6.68 (3.20)	6.93 (3.56)	6.83 (3.59)	F(4,146) = 0.38, p = .825

Note: Standard Deviations are presented in parentheses.

Table 3
Mean pre- and post-lunch hunger ratings, and details on leftover lunch food.

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
Pre-meal hunger	5.3 (2.6)	6.4 (2.2)	6.4 (1.6)	5.7 (2.7)	5.3 (1.8)	F(4,146) = 1.90, p = .114
Post-meal hunger	1.2 (1.4)	1.7 (2.1)	2.0 (1.8)	1.5 (1.7)	1.7 (0.6)	F(4,146) = 0.89, p = .470
Mean weight of leftover food	16.40 (39.51)	20.17 (40.09)	14.23 (35.76)	12.17 (32.41)	25.23 (51.03)	F(4,146) = 0.50, p = .737
Number of participants who did not finish meal	6	8	5	4	7	$X^2(4) = 2.17$, p = .704

Note: Standard Deviations are presented in parentheses.

Table 4
Mean pre- and post-imagination task hunger ratings, and mean ratings of the extent to which the different imagination tasks were immersive, real, detailed, believable, and easy to imagine.

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
Pre-imagination hunger	4.1 (2.5)	4.6 (2.5)	5.6 (2.1)	4.4 (2.5)	4.2 (2.5)	F(1,146) = 1.78, p = .137
Post-imagination hunger	4.1 (2.7)	5.0 (2.9)	4.6 (2.0)	4.9 (2.5)	4.1 (2.4)	F(4,146) = 0.92, p = .454
Imagined events were immersive	4.1 (0.8)	3.7 (0.8)	3.5 (0.8)	3.8 (0.8)	3.7 (0.9)	F(4,146) = 2.34, p = .058
Imagined events seemed real	3.9 (0.9)	3.4 (1.1)	3.3 (0.7)	3.7 (1.0)	3.7 (1.0)	F(4,146) = 2.16, p = .077
Imagined events were detailed	4.0 (1.0)	3.8 (1.0)	3.7 (0.9)	3.9 (0.9)	3.7 (0.8)	F(4,146) = 0.92, p = .455
Imagined events were believable	4.0 (0.7)	3.6 (1.2)	3.6 (1.0)	3.4 (1.3)	4.0 (0.8)	F(4,146) = 2.33, p = .058
Events were easy to imagine	4.5 (0.7)	4.1 (1.0)	4.0 (0.8)	4.3 (0.9)	4.3 (0.8)	F(4,146) = 1.77, p = .138

Note: Standard Deviations are presented in parentheses.

Table 5
Mean biscuit intake and liking in the different experimental conditions.

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
Biscuit intake (g)	72.03 (36.69)	70.03 (39.10)	51.10 (24.55)	75.87 (39.81)	75.53 (34.50)	F(4,146) = 2.88, p = .025*
Average biscuit liking	56.3 (15.4)	66.1 (13.4)	61.6 (16.2)	62.9 (16.1)	57.7 (16.0)	F(4,146) = 1.98, p = .101

Note: Standard Deviations are presented in parentheses.
* = significant at $p < .05$.

model. Post-hoc tests revealed that all comparisons with the 'Recall + Rumination' group (except for the comparison with 'Recall + Enlargement') returned a BF10 value of less than 0.5, indicating evidence in favour of the null model. The analysis indicated anecdotal evidence in favour of the alternative model when comparing the 'Recall + Enlargement' group to the 'Recall + Rumination' group (BF10 = 1.99), moderate evidence when comparing 'Recall + Enlargement' with 'Recall + Handling' (BF10 = 5.47) and 'Food Picture + Handling' (BF10

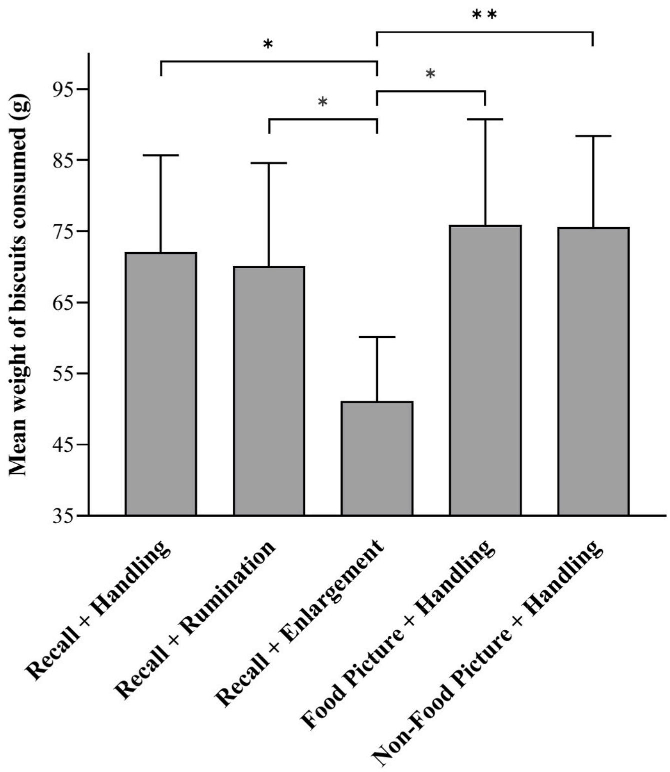

Fig. 1. Mean biscuit intake (g), as a function of the different imagination tasks. Error bars show 95% CI.
Note: * = significant at p < .05; ** = significant at p < .01.

= 7.57), and strong evidence when comparing to 'Non-Food Picture + Handling' (BF10 = 15.38).

3.7. Individual differences

In order to assess how the visualisation exercises affected subsequent intake, as well as the remembered portion size, the size of the lunch offered to participants was kept constant, irrespective of their sex, age, and other individual differences. An additional ANCOVA was conducted to assess the extent to which post-lunch hunger influenced the relationship between the visualisation exercise and biscuit intake. The analysis revealed no significant effect of post-lunch hunger, $F(1,145) = 0.06$, $p = .807$, and the overall model remained significant, $F(5,145) = 2.30$, $p = .048$, $\eta_p^2 = 0.073$. In a similar vein, neither pre- nor post-imagination task hunger ratings were significant covariates in the model, $F(1,145) = 2.44$, $p = .121$ and $F(1,145) = 3.10$, $p = .081$, respectively. Other variables which could have influenced the observed relationship between the imagination task and biscuit intake were sex, age, and BMI. The model remained significant when controlling for these factors, $F(7,143) = 2.16$, $p = .041$, $\eta_p^2 = 0.096$, and none of the variables were significant covariates (all $p > .09$). To investigate the role of restraint in moderating the meal-recall effect, the main ANOVA (with biscuit intake as the dependent variable, and condition as the independent variable) was re-run, with DEBQ restraint as a potential moderator. The analysis was not significant, $F(1,145) = 0.62$, $p = .433$.

3.8. Portion size estimation

It was hypothesised that the different imagination tasks may influence subsequent perception of the lunch portion received. A one-sample *t*-test was conducted to test whether physical portion estimates in each condition were significantly different from the true portion size (300g). All groups underestimated the portion they had received, but to different degrees (see Fig. 2). Portion estimates were significantly smaller than the test value of 300g only in the 'Recall + Enlargement' condition ($M = 269.42$g, $SD = 55.12$), $t(30) = -3.09$, $p = .004$, Cohen's $d = -0.55$ (medium). No other group reached statistical significance ('Recall + Handling': $M = 277.30$, $SD = 67.85$, $t(29) = -1.83$, $p = .077$; 'Recall + Rumination': $M = 282.73$, $SD = 61.80$, $t(29) = -1.53$, $p = .137$; 'Food Picture + Handling': $M = 286.03$, $SD = 50.59$, $t(29) = -1.51$, $p = .141$; 'Non-Food + Handling': $M = 282.73$, $SD = 46.64$, $t(29) = -2.03$, $p = .052$).

Physical portion estimations were not significantly different across all groups, $F(4,146) = 0.40$, $p = .807$. The estimated portion size was not correlated with the total weight of biscuits consumed across all groups, $r = -0.06$, $p = .465$. No relationship between these variables was observed when each condition was investigated separately (recall + handling: $r = -0.26$, $p = .171$; recall + rumination: $r = -0.20$, $p = .283$; recall + enlargement: $r = 0.15$, $p = 431$; food picture + handling: $r = 0.01$, $p.954$; non-food picture + handling: $r = -0.05$, $p = .778$).

4. Discussion

The present experiment aimed to investigate how recalling a recent meal, and then mentally visualising it in different ways, influenced subsequent snacking behaviour. The experiment involved serving a fixed lunch to participants and asking them to perform a mental visualisation task 3 h later. The two main visualisation tasks involved recalling the lunch meal and then either vividly recalling the details of the consumption episode ('Recall + Rumination') or imagining the meal was larger and more filling than in reality ('Recall + Enlargement'). Snacking rates in these conditions were compared to three control conditions: in one group participants recalled a recent meal and then imagined moving it around the plate ('Recall + Handling'). In the other two conditions participants did not recall the recent meal at all. Instead,

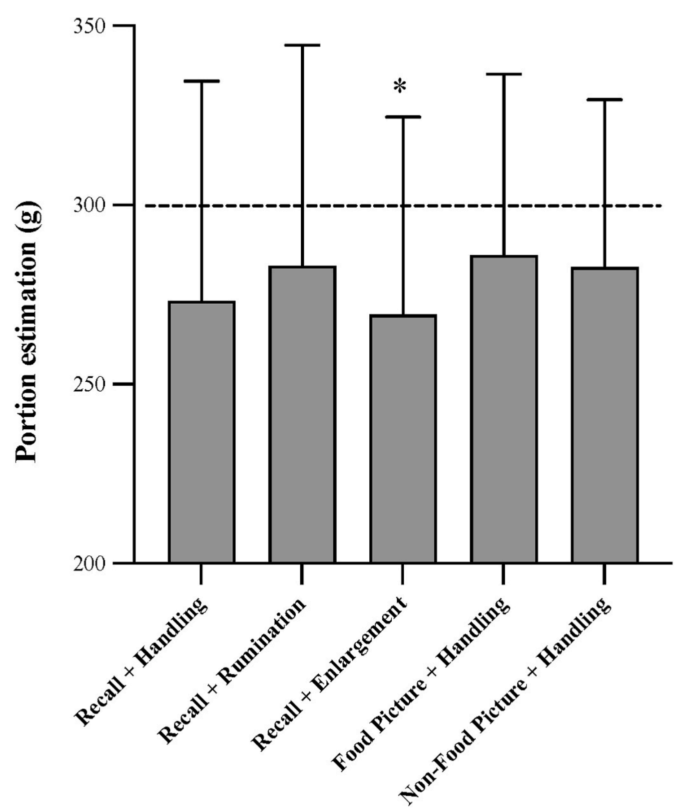

Fig. 2. Mean weight (g) of estimated portion sizes across the experimental conditions. The dashed line denotes true weight of the lunch portion served.
Note: * = significant at p < .05.

they either viewed a picture of a meal they had not eaten ('Food Picture + Handling') or a picture of some stationery on a plate ('Non-Food Picture + Handling') and then imagined moving the new meal or the stationery around the plate.

It was hypothesised that recalling a recent meal and then vividly reliving the experience of having eaten the meal would lead to a reduction of biscuit intake. It was also predicted that imagining a recent meal as bigger and more satiating than in reality would suppress biscuit intake over and above the reduction usually observed after meal recall. Participants estimated the portion of their lunch meal after performing the imagination task as a measure of remembered intake. It was expected that imagining a recent meal as bigger would result in an overestimation of the true portion size.

These hypotheses were partially supported by the data. Imagining the meal as bigger and more satiating in the 'Recall + Enlargement' condition was a successful strategy to reduce biscuit intake, with participants consuming around 24g fewer biscuits on average than those in the 'Non-Food Picture + Handling' condition. In fact, significantly fewer biscuits were consumed in the 'Recall + Enlargement' condition than in all of the other conditions, highlighting how effective this imagination task was at decreasing intake. Unexpectedly, the meal-recall effect (i.e. eating fewer biscuits after recalling a recent meal) was not fully replicated in the present experiment, as significant biscuit reduction was only observed in the 'Recall + Enlargement' group. Recalling a recent meal and then visualising the food moving around the plate, or vividly recalling the details of the consumption episode (e.g. what it felt like to chew and swallow the food), did not affect biscuit intake. This seems to suggest that the meal-recall effect is easily disrupted by contextual factors and might not be reliably observed if additional cognitive tasks are also performed soon after recalling a recent meal. Similar findings were observed in our previous study (Szypula et al., 2020), in which simply changing the mode of recall (written vs. verbal), or depth of recall (unguided vs. guided) had profound effects on the way in which the meal-recall effect manifested. Additionally, recalling a recent meal after positive mood induction also seemed to disrupt the meal-recall effect, potentially because of the increased demands placed on attentional resources (Collins & Stafford, 2015). Thus, it appears that the meal-recall effect is best elicited when minimal cognitive processing of information is required, and simple instructions to recall a recent meal, without prompts for further details, seem most likely to produce the effect.

4.1. Reduced intake

Recalling a recent meal and then imagining that it was bigger than in reality was a very effective method of reducing biscuit intake. Participants in this group consumed over 32% fewer biscuits, which translated to about 122 fewer calories being consumed – a meaningful reduction in the context of weight management. Our previous results suggested that recalling a recent meal reduces intake by about 14% (Szypula et al., 2020) and so this additional imagination task seems to have a beneficial effect on reducing consumption, over and above the meal-recall effect (at this point, it is worth noting that, although this difference between intake in the two studies seems meaningful, Szypula et al., 2020 had a within-subjects design, whereas the present experiment employed a between-subjects design, and so caution should be exerted when comparing the two results). This difference between the two study designs might also imply that meal-recall and visualisation may differentially impact different people. It may be that recalling a veridical recent meal might be more appropriate for *weight maintenance*, while *weight loss* may be better aided by the addition of the imagination element. This possibility could be addressed by future research in the area.

One suggestion to explain why the imagination task was so effective at reducing the amount of biscuits eaten is that determining how much an individual wants to eat is, at least partially, modulated by previous intake (Almiron-Roig et al., 2013). It has been shown that the volume of a preload (i.e. food consumed a short time before the main consumption episode) has a greater impact on subsequent intake, than its caloric content (Rolls et al., 1998). Perhaps imagining that the previous meal was larger and more satiating than in reality acted as a cognitive 'preload', even though the imagination task did not involve actual consumption. An alternative explanation as to why the imagination task decreased subsequent biscuit intake is that imagining eating so much food and feeling very satiated induced feelings of disgust in participants. A few participants mentioned that imagining the portion as bigger and more filling than in reality made them feel sick or disgusted, but this was mentioned in passing, as they were leaving the laboratory and was therefore not meticulously recorded.

Disgust has an adaptive function in humans, as it discourages contact with things which may carry disease-inducing pathogens (Neuberg, Kenrick, & Schaller, 2011). Disgust not only motivates individuals to avoid the specific items which elicited the aversive response, but to also avoid contact with neutral or even positive items which were near the disgusting item (Morales & Fitzsimons, 2007; Randler et al., 2016). Thus, it may be that imagining the previous meal as bigger made participants feel disgusted, and this feeling carried over into the snacking session, leading to reduced biscuit intake. Encouraging decreased intake through inducing feelings of disgust or shame could lead to disordered eating behaviours such as purging or excessive food restriction, and so if the visualisation task is to be utilised for weight management interventions, it is important to ensure this is not the mechanism through which it operates. In a subsequent study conducted by our lab (Szypula et al., in prep) we showed that imagining meals as bigger repeatedly does not induce feelings of disgust, but more studies are needed to explore the mechanism of both the meal-recall effect, and the imagination task, to establish whether such a method is safe and ethical for suppressing intake.

4.2. Remembered portion size

It was hypothesised that imagining a recent meal as larger than in reality might cause participants to subsequently overestimate the true size of the lunch portion. Contrary to the hypotheses, all of the groups numerically underestimated the size of their lunch, but – while there were no significant differences between groups, this underestimation was only significant in the 'Recall + Enlargement' group. One explanation may be that a contrast effect occurred. In other words, knowing that they had imagined their lunch as bigger than in reality motivated participants to over-compensate their estimations of the true amount, ultimately leading to an underestimation. An alternative, and perhaps more plausible explanation for these results, is that people are simply not accurate when estimating portions. Some research suggests that portion under or overestimations can be inconsistent (Hernández et al., 2006; Lucas, Niravong, Villeminot, Kaaks, & Clavel-Chapelon, 1995), especially for amorphous foods, such as rice (Venter, MacIntyre, & Vorster, 2000). Other research suggests that such amorphous foods tend to be underestimated in general (Faggiano et al., 1992). However, these results should be interpreted with caution, given that the degree of underestimation was small in all cases, and in only one group reached significance.

These findings demonstrate that the reduction in intake observed after imagining a meal as bigger is unlikely to be a result of altered meal memories. Contrary to the initial hypotheses, imagining the lunch portion as bigger and more filling did not seem to reduce intake through compensation for (misremembered) greater intake (i.e. 'I had more to eat at lunch, so I will eat fewer biscuits now'). Although hunger ratings significantly decreased pre-to post-imagination task in the 'Recall + Enlargement' group, it is unlikely this was the sole mechanism driving reduced biscuit intake. Previous studies on the meal-recall effect have not found a concomitant reduction in hunger, so it is possible that the change in hunger ratings can be attributed specifically to the imagination component of the study. Perhaps this could explain why, in this study, just recalling a recent meal led to a 45 kcal (−14.5%) reduction in biscuit intake, but recalling a meal and imagining it as bigger reduced intake by 122 kcal (−32%).

4.3. Potential mechanism

We would like to end the discussion by briefly examining the potential mechanism through which the meal-recall effect arises. To date, the literature has not provided any substantial theories of what might be driving the effect. The relationship between food and memory appears to be an evolutionary adaptation (Seitz, Blaisdell, & Tomiyama, 2021), and so to understand the potential neural underpinnings of the meal-recall effect we can gain much from considering work from nonhuman animal models. Memory for events is dependent on hippocampal function (Scoville & Milner, 1957), and consumption is disrupted in individuals with hippocampal damage (Higgs, Williamson, & Attwood, 2008). Evidence from rodents further suggests that inhibiting the activity of hippocampal neurons right after a meal is finished impairs meal-memory consolidation, resulting in faster initiation of the next meal and greater food intake (Hannapel et al., 2019; Henderson, Smith, & Parent, 2013; Parent, Higgs, Cheke, & Kanoski, 2022). It has also been reported that consuming a meal results in increased presence of biomarkers critical for synaptic plasticity, the process through which new memories are formed (Henderson, Nalloor, Vazdarjanova, & Parent, 2016, 2017; Parent, Higgs, Cheke, & Kanoski, 2021). As such, it appears that hippocampal processing of meal-event memories directly influences subsequent consumption. What is less clear, is by what process it does so.

There are two theories which seem most plausible: increased interoceptive awareness and changes to appetitive signals. Interoception refers to the ability to perceive internally generated bodily signals (e.g. heartbeat rate, gastrointenstinal signals etc.; Craig, 2003). The hippocampus is essential for interoceptive signals to be interpreted properly (Davidson et al., 2010; Higgs, Williamson, Rotshtein, & Humphreys, 2008; Rozin, Dow, Moscovitch, & Rajaram, 1998), and damage to this brain area can result in an inability to integrate satiety signals into decision making processes (such as whether to eat) even after substantial meals (Hebben, Corkin, Eichenbaum, & Shedlack, 1985; Rozin et al., 1998). When people (with intact hippocampi) are less certain about how hungry/satiated they are, and about how much they should be eating, they often use external cues to make their decisions (Lewis et al., 2015). For example, they may rely on biscuit palatability as an external cue as to whether to eat (Herman, Roth, & Polivy, 2003). It is possible that recalling a recent meal provides important contextual information (how much and how recently consumption has occurred) to facilitate the interpretation of ambiguous internal cues. This hypothetical momentary improvement in interoceptive satiety-cue interpretation may lead individuals to rely less on factors such as snack palatability, and more on actual bodily need when choosing how much to consume.

Another mechanism which may or may not work in tandem with the interoception theory is that of changes to appetitive signals after recent meal recall. It is possible that as a meal is remembered, satiety signals which were originally associated with that meal are re-activated, and are therefore more prominent for the individual who is deciding how much food to eat. Although no experiments have directly investigated how participants 're-live' or 're-experience' hunger and satiety signals through memory, evidence from separate lines of memory research suggests this is a plausible suggestion. For instance, it has been shown that brain regions activated during an event are re-activated when remembering that event, producing a sensory "shadow" of the original experience (Danker & Anderson, 2010). fMRI data suggests that activity in the visual association cortex which was present at encoding is reinstated at retrieval (Vaidya, Zhao, Desmond, & Gabrieli, 2002), and the auditory association cortex is activated when encoding and retrieving auditory information (Nyberg, Habib, McIntosh, & Tulving, 2000).

Similar findings have been found for olfactory memories as well (Buckner & Wheeler, 2001). Smith, Henson, Dolan, and Rugg (2004) demonstrated that the overlap in brain activation between encoding and retrieval is also present for emotional stimuli, showing that encoding an image in the context of positive or negative valence subsequently activated brain regions typically involved in positive or negative affect processing at retrieval. These findings suggest that recalling an event generates similar brain activity as encoding (i.e. directly experiencing) an event. Therefore, it is plausible to assume that recalling a meal-memory could re-instate satiety signals which were originally associated with the eating episode; these signals could either be a 're-activated' version of the original satiety signals, or completely novel satiety signals generated in response to the 're-activation' of the sensory properties of the consumption event itself (similar to the satiety generated during simulated consumption (Morewedge et al., 2010). A caveat of this theory is that no studies into the meal-recall effect have observed any significant changes pre-to post-recall in terms of hunger, satiety, or desire to eat. It could be that traditional appetite measures (e.g. a 1–10 Likert rating scale) are simply not sensitive enough to reflect these potential changes (Karalus & Vickers, 2016), and the use of other appetite measures might help to explore this mechanism further (Karalus, 2011). In sum, at present it is unclear what is driving the meal-recall effect, and further research is required to fully understand the link between memory and intake.

4.4. Summary

To conclude, the results of this study suggest that a simple imagination exercise might help people eat fewer snacks, but the acceptability and feasibility of such a method to support weight loss requires further testing. Imagining a previous meal as bigger and more satiating than in reality received the lowest scores in terms of how immersive, real, and detailed the imagined events seemed, and some participants mentioned feeling disgusted after the imagination task. The recently consumed meal was remembered as significantly smaller after imagining it was bigger than in reality, however the significance of these results is not clear. An important next step for researchers in this area will be to elucidate what the mechanism of the meal-recall effect, and the visualisation task, might be.

5. Conclusion

The results of the present experiment suggest that asking participants to recall a recent meal and to then imagine it was larger than in reality, can significantly reduce biscuit intake. It was also found that elaborating on meal-memory recalls can disrupt the meal-recall effect, as also shown by our previous study (Szypula et al., 2020). The results suggest that the decrease in biscuit intake was not related to explicit changes in memory for the meal's size. Future research should explore the acceptability and feasibility of imagination tasks as a tool to help people reduce their food intake and support them in their weight loss goals.

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Data access statement

The data supporting the findings reported in this paper are openly available from the UK Data Service Re-Share Repository https://dx.doi.org/10.5255/UKDA-SN-855734.

Ethical statement

Ethical approval has been granted by the Cambridge Psychology Research Ethics Committee prior to data collection. All participants signed a consent form before participating in the experiment, and were fully debriefed at the end of the study. They were also given the chance to withdraw their data from the experiment after learning of the true aims of the study.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

The data supporting the findings reported in this paper are openly available from the UK Data Service Re-Share Repository https://dx.doi.org/10.5255/UKDA-SN-855734.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.106411.

References

Almiron-Roig, E., Palla, L., Guest, K., Ricchiuti, C., Vint, N., Jebb, S. A., et al. (2013). Factors that determine energy compensation: A systematic review of preload studies. *Nutrition Reviews, 71*(7), 458–473. https://doi.org/10.1111/nure.12048

Amoutzopoulos, B., Page, P., Roberts, C., Roe, M., Cade, J., Steer, T., et al. (2020). Portion size estimation in dietary assessment: A systematic review of existing tools, their strengths and limitations. In *Nutrition reviews* (Vol. 78, pp. 885–900). Oxford University Press. https://doi.org/10.1093/nutrit/nuz107, 11.

Anderson, C. A. (1983). Imagination and expectation: The effect of imagining behavioral scripts on personal influences. *Journal of Personality and Social Psychology, 45*(2), 293–305. https://doi.org/10.1037/0022-3514.45.2.293

Arthur, P., Stevenson, R. J., & Francis, H. M. (2021). Recalling a recent meal reduces desire and prospective intake measures for pictures of palatable food. *Applied Cognitive Psychology*. https://doi.org/10.1002/acp.3839. March, 1–7.

Szypula, J. (2021). The Effect of Recent Meal Recall and Its Implications for Weight Loss. https://doi.org/10.17863/CAM.87306.

Vaidya, C. J., Zhao, M., Desmond, J. E., & Gabrieli, J. D. E. (2002). Evidence for cortical encoding specificity in episodic memory: Memory-induced re-activation of picture processing areas. *Neuropsychologia, 40*(12), 2136–2143.

van den Bergh, D., van Doorn, J., Marsman, M., Draws, T., van Kesteren, E.-J., Derks, K., et al. (2020). A tutorial on conducting and interpreting a bayesian ANOVA in JASP. *L'Année Psychologique, 120*(1), 73–96.

Brunstrom, J. M., Burn, J. F., Sell, N. R., Collingwood, J. M., Rogers, P. J., Wilkinson, L. L., et al. (2012). Episodic memory and appetite regulation in humans. *PLoS One, 7*(12), Article e50707. https://doi.org/10.1371/journal.pone.0050707

Buckner, R. L., & Wheeler, M. E. (2001). The cognitive neuroscience of remembering. *Nature Reviews Neuroscience, 2*(9), 624–634. https://doi.org/10.1007/s00221-010-2315-2

Collins, R., & Stafford, L. D. (2015). Feeling happy and thinking about food. Counteractive effects of mood and memory on food consumption. *Appetite, 84*, 107–112. https://doi.org/10.1016/j.appet.2014.09.021

Craig, A. D. (2003). Interoception: The sense of the physiological condition of the body. *Current Opinion in Neurobiology, 13*(4), 500–505. https://doi.org/10.1016/S0959-4388(03)00090-4

Crowley, V. E. F. (2008). Overview of human obesity and central mechanisms regulating energy homeostasis. *Annals of Clinical Biochemistry, 45*(3), 245–255. https://doi.org/10.1258/acb.2007.007193

Danker, J., & Anderson, J. (2010). The ghosts of brain states past: Remembering reactivates the brain regions engaged during encoding. *Psychological Bulletin, 136*(1), 87–102. https://doi.org/10.1161/CIRCULATIONAHA.110.956839

Davidson, T. L., Kanoski, S. E., Chan, K., Clegg, D. J., Benoit, S. C., & Jarrard, L. E. (2010). Hippocampal lesions impair retention of discriminative responding based on energy state cues. *Behavioral Neuroscience, 124*(1), 97–105. https://doi.org/10.1037/a0018402

De Keyzer, W., Huybrechts, I., De Maeyer, M., Ocké, M., Slimani, N., Van 'T Veer, P., et al. (2011). Food photographs in nutritional surveillance: Errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption. *British Journal of Nutrition, 105*(7), 1073–1083. https://doi.org/10.1017/S0007114510004551

Dovey, T. M. (2010). The energy demands of the brain: Central mechanisms of eating. In *Eating behaviour* (pp. 18–36). Open University Press.

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology, 79*(4), 481–492.

Faggiano, F., Vineis, P., Cravanzola, D., Pisani, P., Xompero, G., Riboli, E., et al. (1992). Validation of a method for the estimation of food portion size. *Epidemiology, 3*(4), 379–382. https://doi.org/10.1097/00001648-199207000-00015

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fedoroff, I. C., Polivy, J., & Herman, C. P. (1997). The effect of pre-exposure to food cues on the eating behavior of restrained and unrestrained eaters. *Appetite, 28*.

Hannapel, R., Ramesh, J., Ross, A., Lalumiere, R. T., Roseberry, A. G., & Parent, M. B. (2019). Postmeal optogenetic inhibition of dorsal or ventral hippocampal pyramidal neurons increases future intake. *ENeuro, 6*(1). https://doi.org/10.1523/ENEURO.0457-18.2018

Hebben, N., Corkin, S., Eichenbaum, H., & Shedlack, K. (1985). Diminished ability to interpret and report internal states after bilateral medial temporal resection: Case H. M. *Behavioral Neuroscience, 99*(6), 1031–1039. https://doi.org/10.1037/0735-7044.99.6.1031

Henderson, Y. O., Nalloor, R., Vazdarjanova, A., Murphy, A. Z., & Parent, M. B. (2017). Sex-dependent effects of early life inflammatory pain on sucrose intake and sucrose-associated hippocampal Arc expression in adult rats. *Physiology and Behavior, 173*, 1–8. https://doi.org/10.1016/j.physbeh.2017.01.025

Henderson, Y. O., Nalloor, R., Vazdarjanova, A., & Parent, M. B. (2016). Sweet orosensation induces Arc expression in dorsal hippocampal CA1 neurons in an Experience-dependent manner. *Hippocampus, 26*(3), 405–413. https://doi.org/10.1002/hipo.22532

Henderson, Y. O., Smith, G. P., & Parent, M. B. (2013). Hippocampal neurons inhibit meal onset. *Hippocampus, 23*(1), 100–107. https://doi.org/10.1002/hipo.22062

Herman, C. P., Roth, D. A., & Polivy, J. (2003). Effects of the presence of others on food intake: A normative interpretation. *Psychological Bulletin, 129*(6), 873–886. https://doi.org/10.1037/0033-2909.129.6.873

Hernández, T., Wilder, L., Kuehn, D., Rubotzky, K., Moser-Veillon, P., Godwin, S., et al. (2006). Portion size estimation and expectation of accuracy. *Journal of Food Composition and Analysis, 19*(SUPPL), 14–21. https://doi.org/10.1016/j.jfca.2006.02.010

Higgs, S. (2002). Memory for recent eating and its influence on subsequent food intake. *Appetite, 39*(2), 159–166. https://doi.org/10.1006/appe.2002.0500

Higgs, S. (2008). Cognitive influences on food intake: The effects of manipulating memory for recent eating. *Physiology and Behavior, 94*(5), 734–739. https://doi.org/10.1016/j.physbeh.2008.04.012

Higgs, S., & Spetter, M. S. (2018). Cognitive control of eating: The role of memory in appetite and weight gain. *Current Obesity Reports, 7*(1), 50–59. https://doi.org/10.1007/s13679-018-0296-9

Higgs, S., Williamson, A. C., & Attwood, A. S. (2008). Recall of recent lunch and its effect on subsequent snack intake. *Physiology and Behavior, 94*(3), 454–462. https://doi.org/10.1016/j.physbeh.2008.02.011

Higgs, S., Williamson, A. C., Rotshtein, P., & Humphreys, G. W. (2008). Sensory-specific satiety is intact in amnesics who eat multiple meals: Research report. *Psychological Science, 19*(7), 623–628. https://doi.org/10.1111/j.1467-9280.2008.02132.x

JASP Team. (2022). Jasp (0.16.3). https://jasp-stats.org/download/.

Kappes, H. B., & Morewedge, C. K. (2016). Mental simulation as substitute for experience. *Social and Personality Psychology Compass, 10*(7), 405–420. https://doi.org/10.1111/spc3.12257

Karalus, M. (2011). The creation and testing of a scale to measure the subjective experiences of hunger and satiety [the university of Minnesota]. In *The university of Minnesota digital conservancy*. https://conservancy.umn.edu/bitstream/handle/11299/113165/Karalus_umn_0130E_12101.pdf?sequence=1.

Karalus, M., & Vickers, Z. (2016). Satiation and satiety sensations produced by eating oatmeal vs. oranges. a comparison of different scales. *Appetite, 99*, 168–176. https://doi.org/10.1016/j.appet.2016.01.012

Lewis, H. B., Forwood, S. E., Ahern, A. L., Verlaers, K., Robinson, E., Higgs, S., et al. (2015). Personal and social norms for food portion sizes in lean and obese adults. *International Journal of Obesity, 39*(8), 1319–1324. https://doi.org/10.1038/ijo.2015.47

Loftus, E. F. (1977). Shifting color memory. *Memory & Cognition, 5*(6), 696–699.

Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning & Memory, 4*(1), 19–31. https://doi.org/10.1037/0278-7393.4.1.19

Loftus, E. F., & Pickrell, J. (1995). The Formation of false memories. *Psychiatric Annals, 25*(12), 720–725.

Lucas, F., Niravong, M., Villeminot, S., Kaaks, R., & Clavel-Chapelon, F. (1995). Estimation of food portion size using photographs: Validity, strengths, weaknesses and recommendations. *Journal of Human Nutrition and Dietetics, 8*, 65–74.

Morales, A. C., & Fitzsimons, G. J. (2007). Product contagion: Changing consumer evaluations through physical contact with "disgusting" products. *Journal of Marketing Research, 44*(2), 272–283. https://doi.org/10.1509/jmkr.44.2.272

Morewedge, C. K., Huh, Y. E., & Vosgerau, J. (2010). Thought for food: Imagined consumption reduces actual consumption. *Science, 330*(6010), 1530–1533. https://doi.org/10.1126/science.1195701

Murkin, E., Cole, D. C., Kearney, J. P., Sheeshka, J., Dawson, J., Project, W. N., et al. (2003). Fish consumption practices among frequent consuming Fishers of five ontario great lakes areas of concern (AOCs). *Internat. Assoc. Great Lakes Res, 29*(3).

Narumi, T., Ban, Y., Kajinami, T., Tanikawa, T., & Hirose, M. (2012). Augmented perception of satiety: Controlling food consumption by changing apparent size of food with augmented reality. In *Conference on human factors in computing systems - proceedings* (pp. 109–118). https://doi.org/10.1145/2207676.2207693

Nash, R. A., Wade, K. A., & Lindsay, D. S. (2009). Digitally manipulating memory: Effects of doctored videos and imagination in distorting beliefs and memories. *Memory & Cognition, 37*(4), 414–424. https://doi.org/10.3758/MC.37.4.414

Nelson, M., Atkinson, M., & Darbyshire, S. (1996). Food photography II: Use of food photographs for estimating portion size and the nutrient content of meals. *British Journal of Nutrition, 76*, 31–49.

Neuberg, S. L., Kenrick, D. T., & Schaller, M. (2011). Human threat management systems: Self-protection and disease avoidance. *Neuroscience & Biobehavioral Reviews, 35*(4), 1042–1051. https://doi.org/10.1016/j.neubiorev.2010.08.011

Nyberg, L., Habib, R., McIntosh, A. R., & Tulving, E. (2000). Reactivation of encoding-related brain activity during memory retrieval. *Proceedings of the National Academy of Sciences of the United States of America, 97*(20), 11120–11124. https://doi.org/10.1073/pnas.97.20.11120

Parent, M. B., Higgs, S., Cheke, L. G., & Kanoski, S. E. (2021). Memory and eating: A bidirectional relationship implicated in obesity. *Neuroscience & Biobehavioral Reviews*. https://doi.org/10.1016/j.neubiorev.2021.10.051

Parent, M. B., Higgs, S., Cheke, L. G., & Kanoski, S. E. (2022). Memory and eating: A bidirectional relationship implicated in obesity. In *Neuroscience and biobehavioral reviews* (Vol. 132, pp. 110–129). Elsevier Ltd. https://doi.org/10.1016/j.neubiorev.2021.10.051.

Randler, C., Desch, I. H., Otte im Kampe, V., Wüst-Ackermann, P., Wilde, M., & Prokop, P. (2016). Anxiety, disgust and negative emotions influence food intake in humans. *International Journal of Gastronomy and Food Science, 7*(November 2016), 11–15. https://doi.org/10.1016/j.ijgfs.2016.11.005

Rolls, B. J., Castellanos, V. H., Halford, J. C., Kilara, A., Panyam, D., Pelkman, C. L., et al. (1998). Volume of food consumed affects satiety in men. *American Journal of Clinical Nutrition, 67*(6), 1170–1177. https://doi.org/10.1093/ajcn/67.6.1170

Rolls, B. J., Morris, E. L., & Roe, L. S. (2002). Portion size of food affects energy intake in normal-weight and overweight men and women. *American Journal of Clinical Nutrition, 76*, 1207–1213.

Rozin, P., Dow, S., Moscovitch, M., & Rajaram, S. (1998). What causes humans to begin and end a meal? A role for memory for what has been eaten, as evidenced by a study of multiple meal eating in amnesic patients. *Psychological Science, 9*(5), 392–396. https://doi.org/10.1111/1467-9280.00073

Schacter, D. L., Guerin, S. A., & St Jacques, P. L. (2011). Memory distortion: An adaptive perspective. *Trends in Cognitive Sciences, 15*(10), 467–474. https://doi.org/10.1016/j.tics.2011.08.004

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology, Neurosurgery & Psychiatry, 20*(11), 11–21.

Seitz, B. M., Blaisdell, A. P., & Tomiyama, A. J. (2021). Calories count: Memory of eating is evolutionarily special. *Journal of Memory and Language, 117*(July 2020), Article 104192. https://doi.org/10.1016/j.jml.2020.104192

van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch eating behavior questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders, 5*(2), 295–315. https://doi.org/10.1002/erv.2448

Smith, A. P. R., Henson, R. N. A., Dolan, R. J., & Rugg, M. D. (2004). fMRI correlates of the episodic retrieval of emotional contexts. *NeuroImage, 22*(2), 868–878. https://doi.org/10.1016/j.neuroimage.2004.01.049

Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure dietary restraint, desinhibition and hunger. *Journal of Psychosomatic Research, 29*(I), 71–83.

Szypula, J., Ahern, A., & Cheke, L. (2020). The role of memory ability, depth and mode of recall in the impact of memory on later consumption. *Appetite, 149*(February), Article 104628. https://doi.org/10.1016/j.appet.2020.104628

Vartanian, L. R., Chen, W. H., Reily, N. M., & Castel, A. D. (2016). The parallel impact of episodic memory and episodic future thinking on food intake. *Appetite, 101*, 31–36. https://doi.org/10.1016/j.appet.2016.02.149

Venter, C. S., MacIntyre, U. E., & Vorster, H. H. (2000). The development and testing of a food portion photograph book for use in an African population. *Journal of Human Nutrition and Dietetics, 13*(3), 205–218. https://doi.org/10.1046/j.1365-277X.2000.00228.x

Weinstein, Y., & Shanks, D. R. (2010). Rapid induction of false memory for pictures. *Memory, 18*(5), 533–542. https://doi.org/10.1080/09658211.2010.483232

White, N. M., & McDonald, R. J. (2002). Multiple parallel memory systems in the brain of the rat. *Neurobiology of Learning and Memory, 77*(2), 125–184. https://doi.org/10.1006/nlme.2001.4008

Wilkinson, L. L., Hinton, E. C., Fay, S. H., Ferriday, D., Rogers, P. J., & Brunstrom, J. M. (2012). Computer-based assessments of expected satiety predict behavioural measures of portion-size selection and food intake. *Appetite, 59*(3), 933–938. https://doi.org/10.1016/j.appet.2012.09.007

Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annual Review of Psychology, 55*, 235–269. https://doi.org/10.1146/annurev.psych.55.090902.141555

Yeomans, M. R., Milton, M. R., & Chambers, L. (2017). Additive effects of sensory-enhanced satiety and memory for recent eating on appetite. *Appetite, 117*, 335–341. https://doi.org/10.1016/j.appet.2017.07.018