Seguias, L & Tapper, K. (2018). The effect of mindful eating on subsequent intake of a high calorie snack. *Appetite, 121*, 93-100.

The Effect of Mindful Eating on Subsequent Intake of a High Calorie Snack

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Shortened title: Mindful Eating

Keywords: mindfulness; present moment awareness; eating; calories, food intake; memory

Abstract

This study examined the effects of applying a mindful eating strategy during lunch on subsequent intake of a palatable snack. It also looked at whether this effect occurred due to improved memory for lunch and whether effects varied with participant gender, level of interoceptive awareness or sensitivity to reward. Participants (n = 51) completed a heartbeat perception task to assess interoceptive awareness. They were then provided with a lunch of 825 calories. Participants in the experimental group ate lunch while listening to an audio clip encouraging them to focus on the sensory properties of the food (e.g. its smell, look, texture). Those in the control group ate lunch in silence. Two hours later participants were offered a snack. They then completed a questionnaire assessing sensitivity to reward as well as other measures assessing various aspects of their memory for lunch. The results showed no significant difference in lunch intake between the two groups but participants in the experimental group consumed significantly less snack than those in the control group; mean = 112.30 calories (SD = 70.24) versus mean = 203.20 calories (SD = 88.05) respectively, Cohen's d = 1.14. This effect occurred regardless of participant gender or level of interoceptive awareness. There was also no significant moderation by sensitivity to reward although one aspect, reward interest, showed a trend towards significance. There was no evidence to indicate that the mindful eating strategy enhanced participants' memory for their lunch. Further research is needed to assess the long-term effects of this strategy, as well as establish the underlying mechanisms. Future work on the relationship between sensitivity to reward and the effects of mindful eating may also benefit from larger sample sizes.

Introduction

Mindful eating can be described as a “non-judgmental awareness of physical and emotional sensations associated with eating” (Framson et al., 2009). Elements of mindful eating are increasingly being incorporated into interventions designed to facilitate weight loss and manage obesity-related eating behaviours (Olsen & Emery, 2015). Although such interventions are often associated with improvements in eating behaviours and weight management, the extent to which these effects are driven by mindful eating is unclear (Olsen & Emery, 2015; O’Reilly, Cook, Spruijt-Metz, & Black, 2014; Tapper, 2017).

The current study takes just one aspect of mindful eating, attending to the sensory properties of food, and examines its effects on eating in a more controlled laboratory setting. Previous research using this type of strategy has failed to find any immediate effect on food intake i.e. while the strategy is being applied (Bellisle & Dalix, 2001; Cavanagh, Vartanian, Herman, & Polivy, 2014; Long, Meyer, Leung, & Wallis, 2011). Other studies, however, have found that focusing on the sensory properties of food is associated with reduced food intake at a later point (Arch et al., 2016; Cavanagh et al., 2014; Higgs & Donohoe, 2011). For example, Higgs and Donohoe (2011) examined the effect of focusing on the sensory properties of lunch on cookie consumption 2 to 3 hours later among female participants. Results showed that those who were asked to focus on the sensory properties of their lunch consumed fewer cookies (a difference of 27 grams) in comparison to those who ate lunch while reading an article about food or those who ate lunch without any manipulation. Similar results were also attained by Robinson, Kersbergen, and Higgs (2014), whereby overweight and obese female participants who focused on the sensory properties of their food during lunch showed a 30 % reduction in consumption of an afternoon snack (equivalent to 106 calories).

To explain the above findings, Higgs and Donohoe (2011) suggested that attending to the sensory properties of food enhanced participants’ memory for it, which subsequently helped them appropriately interpret physiological signals in the afternoon and adjust their cookie consumption accordingly. This interpretation was supported by the fact that, compared to those in the control condition, participants in the experimental condition rated their memory of the lunch they had consumed as more vivid. However, Robinson et al. (2014) failed to replicate this effect on memory, possibly because of ceiling effects in their measurement of memory vividness. They also explored another aspect of memory, memory of quantity of food consumed, but again failed to find evidence that it mediated the relationship between the focused attention manipulation and reduced intake. As such they suggested that interoceptive memory (i.e. memory of level of hunger and fullness after lunch) may be more important.

The current study extends this research in a number of ways. First it examines whether the effects of focusing on the sensory properties of food extends to males as well as females. Both studies conducted by Higgs and Donohoe (2011) and Robinson et al. (2014) were restricted to females. However, given gender differences in eating behaviour and food-related concerns (Missagia, Oliveira, & Rezende, 2013; Nowak & Speare, 1996) it would be unwise to assume we would necessarily obtain similar results with males. Second, the study explores in more detail the role of memory as a mechanism to explain the effects of mindful eating on subsequent food intake. It does so by examining four different types of memory: interoceptive memory, memory vividness, memory for quantity of food consumed, and memory for type of food consumed. And third, the study explores whether the effects of the mindful eating strategy are moderated by individual differences in interoceptive awareness and sensitivity to reward.

Interoceptive awareness is the ability to detect inner bodily states or signals like heartbeat and feelings of satiety (Herbert, Blechert, Hautzinger, Matthias, & Herbert, 2013). Previous research has shown that a positive relationship exists between levels of interoceptive awareness and ones ability to recognise, and respond to, signals of hunger and fullness (Herbert et al., 2013). Whilst interoceptive awareness may not be amenable to change via mindfulness practice (Melloni et al., 2013; Parkin et al., 2014) it is possible that it may moderate its effects. For example, the mindful eating manipulation may work by increasing individuals' attention toward feelings of satiety which may in turn enhance interoceptive memory. As such we would expect it to be less effective amongst those with lower levels of interoceptive awareness, since they would be less able to detect such feelings in the first place.

Research has also shown that individuals with a higher sensitivity to reward tend to be more responsive to appetising foods and food cues (Tapper, Pothos, & Lawrence, 2010), show an increased tendency to overeat (Davis et al., 2007) and consume more fat in their diet (Tapper, Baker, Jiga-Boy, Haddock, & Maio, 2015). As such, participants high in sensitivity to reward may be inclined to eat appetizing foods irrespective of their level of satiety. Thus again we may find that the mindful eating strategy is less effective at reducing intake of a highly palatable snack amongst those with higher sensitivity to reward. For this study a relatively new measure of reward sensitivity was employed; The Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ; Corr & Cooper, 2016). This measure was selected as it addresses some of the problems with previous measures and better aligns with recent revisions to Reward Sensitivity Theory (Corr, 2016; Corr & Cooper, 2016). The RST-PQ includes four subscales relating to reward sensitivity: (1) reward interest; openness to trying new experiences that are potentially rewarding, (2) goal drive persistence; maintenance of motivation especially when reward is not available immediately, (3) impulsivity; tendency to display behaviour that may lack consideration of consequences, and (4) reward reactivity; feelings of pleasure and emotional 'highs' associated with the experience of reward. Because previous studies have found effects with different reward sensitivity subscales (Davis et al., 2007; Tapper et al., 2010; Tapper et al., 2015) and because the subscales in the RST-PQ do not map directly onto those used in previous studies, the effects of each subscale were examined in an exploratory fashion.

Methods

Participants

Originally, 60 male and female participants were recruited. However, two failed to attend the second part of the study leaving a total of 58. These participants had an average age of 24.22 years (*SD* 7.81). Participants were recruited using an advert placed on an online platform affiliated with the university, as well as via flyers and posters placed on billboards around the university buildings. In order to avoid participants guessing that their food consumption was being measured, the study was described as exploring the effect of mood on heart rate perception and taste preferences. Participants who completed the study received course credits or 5 pounds sterling. Inclusion criteria were fluency in English and exclusion criterion were food allergies to any of the foods being offered and being on any medication that could affect appetite. Ethical approval was granted by the City, University of London Psychology Department Research Ethics Committee.

Experimental design

A between-subjects design was used with two conditions: (1) control group where participants ate lunch with no audio recording, (2) experimental group where participants received instructions via an audio recording that asked them to focus on the sensory properties of their lunch whilst eating.

Test foods

Lunch. In order to avoid ceiling effects on measures of memory for lunch items consumed, a range of different foods were given to participants for their lunch. These consisted of: one cheese and tomato sandwich (158 grams, 405 kcal), 5 cherry tomatoes (55 grams, 11 kcal), 5 Ritz crackers (19 grams, 95 kcal), 5 red grapes (30 grams, 20 kcal), 5 green grapes (33 grams, 20 kcal), 4 mini lemon cakes (33 grams, 135 kcal) and 4 mini chocolate cakes (32 grams, 139 kcal). The sandwiches comprised two pieces of wholegrain bread cut into 2 triangles. This was presented alongside the cherry tomatoes, crackers, and grapes on a plate. The cakes were presented in a separate bowl. The meal contained approximately 825 calories in total. The amount of food consumed by each participant was calculated by counting the number of foods eaten as well as weighing the foods individually before and after the participant ate their meal. In addition to the food provided, two participants requested a cup of water, which they were given.

Afternoon snack. This consisted of three separate 60 g portions of original (295 kcal), milk chocolate (296 kcal), and dark chocolate (299 kcal) digestive biscuits, each served on a separate plate. The biscuits were broken into smaller pieces to reduce the possibility that participants would keep count of the number they had eaten. The amount of biscuits consumed by each participant was calculated by weighing each plate after the snack session.

Audio clip

The audio clip encouraged participants to focus on the sensory properties of the food i.e. its smell, look, taste, texture, temperature and the physical acts of chewing and swallowing. For example, participants were asked to "…try to really get to know each food while holding it in the palm of your hands…", "…notice the sound the food makes as you chew..." and "start to feel the bursting of flavour." They were also asked to think about the taste of the food and whether it reminded them of any similar flavours. The audio clip was 2 minutes and 30 seconds long. It was played on a laptop computer twice at the start of the meal, with a 3-minute gap in between.

Heartbeat perception task

This task was used to measure interoceptive awareness. Participants completed a practice task followed by the actual task. Procedures were similar to those employed by Schandry (1981). Without taking their pulse, participants were asked to silently count the number of heartbeats they felt in their body over four time intervals of 25, 35, 45, and 55 seconds. The start and end of each interval was indicated by a 'GO' and 'STOP' signal that appeared on the computer screen and the four different time intervals were presented in a new random order for each participant. At the stop signal, participants were asked to type in the number of heartbeats they counted. Between each time interval, participants were given a 30 second break. Simultaneously, as participants counted their heartbeats, actual participant heartbeat was recorded via an electrocardiogram (ECG). To attain these recordings, two electrodes were attached to the bottom of the participant's ribs or to their wrists. An electrode was also attached to their elbow at the start of the task. To obtain a measure of interoceptive awareness the number of participant actual heartbeats per interval was compared to the number of heartbeats reported by participants. For each interval, a score for accuracy was calculated:

$$|(1- \frac{actual\ heartbeats - counted\ heartbeats}{actual\ heartbeats})|$$

The mean score across the four intervals was then computed for each participant to produce a final value between 0 and 1. According to previous research a score of 0.85 or less represents lower interoceptive awareness and a score above 0.85 represents higher interoceptive awareness (Herbert, Muth, Pollatos, & Herbert; 2012; Pollatos, Gramann, & Schandry, 2007).

Questionnaires

Appetite. Appetite was assessed using two questions: (1) how hungry do you feel right now? and (2) how full do you feel like right now? Participants responded by placing a mark along the length of 17 cm long visual analogue scale anchored by 'not at all' and 'extremely'. Participant ratings were obtained by measuring the distance from the left extremity of the line then standardising this figure to produce a score from 0 to 10.

Memory. The first part of this questionnaire asked participants to rate how vividly they remembered the lunch they consumed. It also assessed participant interoceptive memory by asking participants to rate how hungry and how full they were immediately after lunch. Participants responded to all three questions via the same visual analogue scale that was used to measure appetite. In order to compute interoceptive memory, participant level of hunger (collected after lunch) was subtracted from their reported memory of this hunger (collected after snack). The same calculation was also conducted for level of fullness. All negative signs were then removed from these scores, meaning that higher scores indicated a greater discrepancy between reported and remembered hunger / fullness (i.e. indicated poorer memory).

The second part of the questionnaire assessed participant memory for foods eaten. The questionnaire provided participants with two blank columns. The first was labelled 'Food' with the example 'red pepper sticks', and the second was labelled 'Quantity' with the example 'two slices'. Participants were asked to list what they had for lunch in as much detail as possible i.e. to specify the type and quantity of food consumed using the two columns provided.

A coding scheme was created to score participant memory of (1) quantity of each type of food consumed (e.g. 4 grapes) and (2) details of food consumed (i.e. type of cake and colour of grapes). In total, participants were offered the following 5 foods for lunch: 1 cheese and tomato sandwich, 5 cherry tomatoes, 5 Ritz crackers, 10 grapes, and 8 mini cakes. Participants received 1 point for each quantity of food items consumed that they remembered correctly. For example, if a participant had eaten only 1 sandwich, 2 tomatoes, 3 crackers, and 7 grapes, they received a score of 4 if they listed 1 sandwich, 2 tomatoes, 3 crackers, and 7 grapes, but a score of 3 if they listed 1 sandwich, 1 tomato, 3 crackers, and 7 grapes. For analysis purposes, the score received was divided by the overall number of food items (a value between 0-5) consumed by the participant.

Regarding the coding scheme for participant memory of grape colour and cake type, participants were coded as either 'correctly remembered' or 'incorrectly remembered'. Participants who incorrectly specified the colour of the grapes or type of cake eaten were coded as incorrect. For example, if a participant ate green grapes but only listed red grapes, both red and green grapes, or just grapes, they were coded as incorrect. Participants who correctly specified the colour of the grapes or the type of cake eaten were coded as correct. For instance, if a participant ate lemon cake, and listed lemon cake, a code of correct was received regarding memory of cake details.

Two raters independently coded all the data using the above coding schemes. Cohen's κ showed there was perfect agreement in relation to the quantity of each type of food consumed, and details of grapes consumed, $\kappa = 1.00$, $p < 0.001$. Agreement was almost perfect for details of cake consumed, $\kappa = 0.907$, $p < 0.001$.

The reinforcement sensitivity theory personality questionnaire (RST-PQ). This questionnaire, developed by Corr and Cooper (2016), assessed participants' level of sensitivity to reward and punishment via 84 statements describing everyday feelings and behaviours. Participants were asked to rate how much each statement accurately described them on a scale from 1 to 4 where 1 represented not at all and 4 represented highly. For the purpose of this study, only questions relating to the subscales assessing reward interest (7 items), reward reactivity (10 items) impulsivity (8 items), and goal drive persistence (7 items) were considered for analysis. For this study, the reliability coefficients (Cronbach's alpha) for reward interest, reward reactivity, and goal drive persistence were 0.73, 0.72, and 0.8 respectively, indicating an acceptable level of internal consistency, whilst for the impulsivity subscale, the reliability coefficient was 0.46 indicating a low level of internal consistency.

Demographics, snacking and dieting status. Participants were asked to indicate their age and gender, whether they had eaten anything between the lunch and snack sessions and whether they were currently dieting to lose weight.

Procedure

The study was divided into two sessions: the lunch session and the snack session. Upon arrival for the lunch session, participants were alternately allocated to either the control group or the experimental group taking gender into account. Once allocated to a group, the participant completed the heartbeat perception task followed by The Positive and Negative Effect Schedule (PANAS; Watson, Clarke, & Tellegen, 1988) and the appetite questionnaire. The PANAS was used throughout the study to assess participant mood. It was included only to give the participant the impression that the study explored the effect of mood on taste preferences so the data were not analysed. Upon completing the questionnaires, the participant was provided with lunch and told to eat as much as they wanted. In the control group, participants ate lunch with no audio recording and in the experimental group participants ate lunch while listening to the audio recording. The researcher told the participant they would return after 10 minutes and then left them alone in the laboratory to eat their lunch. All participants had finished eating by the time the researcher returned. The participant was then asked to complete the PANAS and appetite questionnaires for a second time as well as a questionnaire assessing their liking of the lunch items. This questionnaire was included to give the participant the impression that the study explored taste preferences so the data were not analysed. Lastly, the participant was thanked and reminded to return 2 hours later for the afternoon snack session.

At the snack session, the participant again completed the PANAS before being presented with the three plates of biscuits and asked to rate their liking for each type of biscuit using the liking of snack items questionnaire. Again, this questionnaire was included to fit with the cover story so the data were also not analysed. The participant was told to eat as much of the biscuits as they liked because what was not eaten would be thrown away. The participant was also told that the researcher would return in 5 minutes. After 5 minutes, the researcher returned to the laboratory and the participant was asked to complete the PANAS, the memory questionnaire, and the RST-PQ. At the end of the snack session, the participant underwent a funnelled suspicion probe before being debriefed about the true aims of the study. Participants were then asked to answer the questions on demographics, snacking and dieting status. Finally, with the participant's consent, their weight and height were measured. The suspicion probe and debrief were conducted prior to the final measures in order to adhere to ethics guidelines on the use of deception, and also because the final measures may have led participants to question the stated aims of the study.

Sample size calculation and statistical analysis

The sample size was determined using data from Robinson et al. (2014). It was assumed participants in the control group would eat an average of 356 calories (*SD* = 185) for snack, and participants in the experimental group would eat an average of 250 calories (*SD* = 92). Assuming

80% power and 5% alpha a sample size of 28 participants per group would be needed to detect a significant effect. In order to allow for attrition, an additional 2 participants were recruited in each group.

Prior to parametric analysis, data were screened for normality. Interoceptive memory for hunger and interoceptive memory for fullness were both positively skewed and so square root transformations were applied. Memory vividness was negatively skewed. Since this was not corrected by transformations, these data were analysed using non-parametric tests. Outliers (defined as >3.5 SDs from the mean) were excluded from relevant parametric analyses. Two-way between subjects anova tests were used to examine the effects of condition and gender on lunch and snack intake. The independent variables were condition (experimental, control) and gender (male, female) whilst the dependent variable was the lunch/snack consumed in calories. Hierarchical regression analyses were used to determine whether interoceptive awareness and sensitivity to reward moderated the effects of condition on snack intake. In step 1, condition and gender were entered. Interoceptive awareness, or the subscales of sensitivity to reward, were then entered at step 2, and the interaction term was entered at step 3. A 2(condition) x 2(memory type) mixed anova was used to examine the effect of condition on interoceptive memory (hunger and fullness). A Mann-Whitney U test was used to test for group differences in memory vividness and independent t-tests were used to test for group differences in memory for lunch items consumed, as well as differences in snack intake between participants who correctly and incorrectly remembered details of food consumed. Chi square was used to determine the relationship between condition and participant memory of details of foods consumed. Pearson's correlation was used to examine whether snack intake was associated with participant interoceptive memory and with memory of quantity of lunch items consumed; Spearman's rho was used to measure the association between snack intake and memory vividness. The statistical analysis package employed was IBM SPSS Statistics (version 22).

Results

Participant characteristics

Seven participants were excluded from the analysis for the following reasons: 6 guessed that food intake was being assessed (3 experimental, 3 control) and 1 misunderstood instructions (experimental). This left a total of 51 participants; 26 in the experimental condition and 25 in the control condition. (Note that due to these exclusions the sample size was smaller than our target sample size.) As shown in Table 1, these two groups were well matched on a range of relevant characteristics, with the exception of gender, for which there were slightly more females in the control condition compared to the experimental condition. Hunger and fullness were both rated as relatively low, suggesting that participants considered themselves neither very hungry nor very full and/or were using the scales conservatively. Importantly, the hunger ratings showed a significant decline following lunch, whilst the fullness ratings showed a significant increase, indicating that participants were employing these scales in a meaningful way.

Table 1. Characteristics of study participants as a function of condition

Characteristic	Experimental (n = 26*)	Control (n = 25*)
Percentage of females	46 %	60 %
Percentage dieting to lose weight	8%	4%
BMI (mean, SD)	23.52 (3.71)	23.26 (3.25)
Age (mean, SD)	22.81 (5.23)	25.80 (10.00)
Fullness before lunch on a scale of 0-10 (mean, SD)	2.23 (1.28)	1.92 (1.31)
Hunger before lunch on a scale of 0-10 (mean, SD)	3.04 (1.60)	3.05 (1.35)
Calories consumed at lunch (mean, SD)	467.68 (212.90)	549.18 (170.51)

*n = 23 (experimental) and n = 22 (control) for BMI due to missing data

In relation to the number of calories consumed at lunch, analysis showed no main effect of condition, $F(1,47) = 2.65$, $p = 0.11$, no main effect of gender, $F(1, 47) = 1.56$, $p = 0.22$, and no interaction between condition and gender, $F(1,47) = 0.22$, $p = 0.64$.

Effect of the mindfulness strategy on snack intake

As shown in Table 2, the amount of snack consumed was higher in the control group compared to the experimental group. It was also slightly higher amongst males compared to females.

Table 2. The amount of snack consumed, in calories, as a function of condition and gender

Condition and gender	Snack intake in calories (mean, SD)
Experimental	
Female (*n* = 12)	84.37 (33.56)
Male (*n* = 14)	136.23 (84.84)
Total (*n* = 26)	112.30 (70.24)
Control	
Female (*n* = 15)	201.90 (89.42)
Male (*n* = 10)	205.16 (90.72)
Total (*n* = 25)	203.20 (88.05)

In line with predictions, analysis showed a significant main effect of condition on snack intake, $F(1,47) = 17.41$, $p < 0.001$, with those in the experimental group consuming fewer calories compared to those in the control group (partial $\eta^2 = 0.27$). However, there was no significant main effect of gender on snack intake, $F(1, 47) = 1.52$, $p = 0.22$ and no significant interaction between condition and gender, $F(1,47) = 1.18$, $p = 0.28$, indicating that the manipulation was effective for both males and females. When the analysis was repeated, but excluding dieters ($n = 48$), the pattern of effects was unchanged. Additionally, seven participants reported eating something in between the lunch and snack sessions (5 experimental, 2 control). However, when these participants were excluded ($n = 44$), again the pattern of effects was unchanged.

Effect of interoceptive awareness on strategy efficacy

Prior to analysis, one outlier in the control group was removed from the data set. The mean score for participant level of interoceptive awareness was 0.69 ($SD = 0.19$). As noted previously, other researchers have suggested that a score above 0.85 indicates high interoceptive awareness whilst a score of 0.85 or lower indicates low interoceptive awareness. According to these criteria, 43 participants in the current study had low levels of interoceptive awareness, and 7 had high levels. As shown in Table 3, neither interoceptive awareness ($R^2 \Delta = 0.10\%$, $p = 0.85$) nor the interaction between interoceptive awareness and condition ($R^2 \Delta = 0.30\%$, $p = 0.69$) significantly predicted snack intake. These results indicate that level of interoceptive awareness did not influence the amount of snack participants consumed nor did it moderate the effects of the mindfulness manipulation on consumption.

Table 3. Linear regression models examining the main and moderating effects of interoceptive awareness (IA) on snack intake (n = 50)

	Snack intake B	SE B	Beta
Step 1			
Constant	183.45	18.09	
Condition[a]	-89.21	21.84	-0.51**
Gender[b]	33.54	21.84	0.19
R^2		0.28**	
Step 2			
Constant	175.79	43.33	
IA	11.30	57.92	0.03
R^2		0.28	
ΔR^2		0.00	
Step 3			
Constant	211.93	100.08	
Condition x IA	64.61	160.90	0.28
R^2		0.28	
ΔR^2		0.00	

* p <. 05

**p < 0.01

[a]control = 0 experimental = 1

[b]females = 0 males = 1

Effect of sensitivity to reward on strategy efficacy

The mean scores for participant level of reward interest, goal drive persistence, impulsivity and reward reactivity were 20.31(SD = 3.82), 22.57 (SD = 4.16), 20.55 (SD = 4.92) and 30.20 (SD = 4.55) respectively. As shown in Table 4, overall sensitivity to reward did not have a main effect on snack intake ($R^2 \Delta$ = 9.40 %, p = 0.18). The subscales of goal drive persistence, impulsivity, and reward reactivity also showed no interaction with condition, ($R^2 \Delta$ = 2.50 %, p = 0.19; $R^2 \Delta$ = 3.00 %, p = 0.15; $R^2 \Delta$ = 2.90 %, p = 0.16 respectively) though the subscale of reward interest showed a trend toward an interaction ($R^2 \Delta$ = 4.90 %, p = 0.06).

Table 4. Linear regression models examining the main and moderating effects of reward reactivity (RR), reward interest (RI), impulsivity (I) and goal drive persistence (GDP) on snack intake (n = 51)

		Snack Intake		
		B	SE B	Beta
Step 1				
	Constant	191.82	18.15	
	Condition[a]	-94.85	22.34	-0.53**
	Gender[b]	28.46	22.37	0.16
R^2			0.28**	
Step 2				
	Constant	220.36	94.71	
	RI	2.54	3.28	0.11
	GDP	-7.44	3.11	-0.34*
	IM	0.19	2.35	0.01
	RR	2.69	3.03	0.13
R^2			0.37	
ΔR^2			0.09	
Step 3				
	Constant	359.97	117.54	
	RI x condition	11.27	5.91	1.33
R^2			0.42	
ΔR^2			0.05	
Step 3				
	Constant	299.28	110.75	
	GDP x condition	7.57	5.64	1.01

R^2			0.40	
ΔR^2			0.03	
Step 3				
	Constant	293.31	105.96	
	IM x condition	6.93	4.74	0.87
R^2			0.40	
ΔR^2			0.03	
Step 3				
	Constant	331.31	121.15	
	RR x condition	7.31	5.07	1.27
R^2			0.40	
ΔR^2			0.03	

* p <. 05

**p < 0.01

[a]control = 0 experimental = 1

[b]females = 0 males = 1

Interoceptive memory

The untransformed data showed that participants in the control group had slightly better interoceptive memory for hunger and fullness after lunch respectively (mean = 0.44, SD = 0.52; mean = 0.39, SD = 0.31, n = 25) compared to those in the experimental group (mean = 0.75, SD = 1.22; mean = 0.61, SD = 0.49, n = 26). However, statistical analysis of the square root transformed data showed no main effect of condition, $F(1, 49) = 1.71$, $p = 0.20$ and no interaction between condition and memory type $F(1, 49) = 0.00$, $p = 0.95$. These results fail to support the hypothesis that the effects of mindful eating on subsequent consumption are brought about by enhanced interoceptive memory. Additionally, there was no significant correlation between memory of hunger and calories of snack consumed ($r = 0.03$, $p = 0.85$) or between memory of fullness and calories of snack consumed ($r = -0.17$ $p = 0.24$), suggesting that more accurate interoceptive memory of hunger and fullness was not associated with reduced food intake.

Memory vividness

A Mann-Whitney U test showed that, contrary to predictions, participants in the control group remembered lunch consumed significantly more vividly (Mdn = 5.59, *n* = 25) compared to participants in the experimental group (Mdn = 4.76 *n* = 26), U(50) = 172, p = .004. Again these findings fail to support the hypothesis that the mindful eating strategy enhanced memory for food consumed. Also contrary to predictions, there was a significant positive relationship between memory vividness and snack intake (r = 0.32, p = 0.02), suggesting the more vividly participants remembered their lunch, the more snack they ate.

Memory for quantity of food consumed.

Participants who ate fewer than 4 different items were excluded from this analysis, leaving a total of 23 participants in the experimental group and 20 in the control group. Using the coding scheme described in the Methods section, scores were calculated for participant memory of the quantity of each food type eaten. The maximum possible score was 5 (i.e. the participant ate all 5 food types and remembered the quantity eaten of each) whilst the minimum score was 0 (i.e. the participant didn't remember the quantity of any foods they had eaten). Analysis showed that participants in the experimental group had a mean score for memory of quantity of food consumed of 2.91 (*SD* = 1.38) whilst those in the control group had a mean score of 2.90 (*SD* = 1.02). This difference was not statistically significant; $t(41)$ = 0.04, p = 0.97, indicating that, contrary to predictions, the mindful eating manipulation did not significantly improve participant memory for quantity of food consumed. There was also no significant relationship between memory of quantity consumed and snack intake (r = -.04, p = 0.80) suggesting that increased accuracy of memory of amount of food consumed did not reduce subsequent intake.

Memory for type of food consumed.

Participants who did not eat any grapes or cake were excluded from this analysis, leaving a total of 46 participants for the analysis of grape colour (24 experimental, 22 control) and 39 for the analysis of cake type (21 experimental, 18 control). The number of participants in the experimental and control groups who correctly and incorrectly remembered the colour of grapes and type of cake they had eaten are presented in Table 5. Analysis indicated that there was no significant association between condition and memory for details of grape colour (*X-squared* (1) = 0.76, p = 0.38, or between condition and memory for details of cake type (*X-squared* (1) = 2.20, p = 0.14. Thus participants in both the experimental and control groups remembered grape colour and cake type equally well, failing to support the hypothesis that participants in the experimental group would have a better memory for the details of the food they had consumed.

Table 5. Number of participants in the experimental and control groups who correctly and incorrectly remembered the colour of grapes and the types of cake they had eaten.

Accuracy and food detail		Experimental	Control
Grape colour			
	Correctly remembered	14	10
	Incorrectly remembered	10	12
Cake type			
	Correctly remembered	13	15
	Incorrectly remembered	8	3

Additionally, there was no significant difference in calories of snack consumed amongst participants who correctly remembered grape colour (Mean = 176.93, SD = 99.90) versus those who did not (Mean = 137.34, *SD* = 83.31); $t(44) = 1.45$, $p = 0.15$. This fails to support the hypothesis that improved meal recall reduces subsequent consumption. Furthermore, there was a significant difference in calories of snack consumed between those who remembered the type of cake eaten compared to those who did not; $t(37) = 2.14$, $p = 0.04$, but this was in the opposite direction to predictions, with those who accurately recalled the cake type consuming more calories of snack than those who did not (Mean = 189.02, *SD* = 97.60 versus Mean = 121.32, *SD* = 58.47 respectively).

Discussion

The results showed that, compared to those in a control condition, participants who ate their lunch while focusing on the sensory properties of their food consumed fewer biscuits two hours later. On average, the difference in intake was equivalent to 18.40 grams or 91 calories, representing a reduction of 45 %. These results are in line with previous research conducted by Higgs and Donohoe (2011) and Robinson et al. (2014), who found reductions in afternoon snack intake averaging 27 grams (51%) and 106 calories (30 %) respectively among participants who focussed on the sensory properties of their food whilst eating lunch. The current study extends this research by employing a sample that includes males as well as females. Although the small sample sizes prevent us from concluding that the manipulation was equally effective irrespective of gender, the means suggest that the reductions in intake were not restricted to females (see Table 2). Further research, with a larger sample, would help establish whether gender moderates the relative efficacy of this manipulation. Additionally, although, not an aim of the current study, the fact that the results failed to show a significant difference in lunch intake between the two groups (i.e. whilst the strategy was being applied) is consistent with other research that has failed to find any immediate effects of this strategy (Bellisle & Dalix, 2001; Cavanagh et al., 2014; Long et al., 2011).

However, the results showed no evidence that the mindful eating manipulation brought about its effects by enhancing participants' memory for their lunch. Specifically, the study failed to find any group differences on measures of interoceptive memory, or memory for the quantity and types of food consumed and, in contrast to the study's hypotheses, found that participants in the control group reported remembering lunch more vividly than those in the experimental group. This latter finding contrasts with Higgs and Donohoe (2011), who reported more vivid memories amongst those in the experimental group, and also with Robinson et al. (2014), who found no group difference. Similarly, in contrast to predictions, there was a positive relationship between memory vividness and snack intake in the current study. The reason for these effects is unclear, though it is possible that engaging in the mindful eating task led participants to interpret the memory vividness question in a slightly different way from those in the control group and to evaluate the vividness of their memory more critically. Indeed, there is evidence to show that engaging in mindfulness practice can change the way in which individuals interpret items on questionnaires designed to assess mindfulness, leading to counterintuitive results showing no difference in measures of mindfulness between experienced mindfulness meditators and those with no experience of mindfulness meditation (Grossman, 2011). This interpretation is consistent with the absence of a group difference in memory for specific details of the foods consumed (i.e. colour of grapes and type of cake) which is arguably an aspect of memory vividness, but a less subjective measure.

The fact that there was no group difference in participants' memory for the quantity of lunch items eaten is in line with Robinson et al. (2014), who found no significant group difference in participants' accuracy at estimating the amount of food they had consumed, nor any relationship between estimate accuracy and snack consumption. Although the measures employed in the two studies are not directly comparable (in the current study participants estimated number of items whilst in Robinson et al. they estimated total calories), both can be viewed as reflecting memory for quantity of food eaten.

The current study extended previous research by also looking at interoceptive memory (i.e. memory for hunger and fullness), but again failed to find any difference between the experimental and control conditions. Thus, despite the fact that previous research has shown that memory plays a role in food consumption (Higgs, 2002; Higgs, Williamson, & Attwood, 2008), the results of the current study suggest that this is unlikely to be the primary mechanism responsible for reduced food intake among those who have attended to the sensory properties of their food during a previous meal. Nevertheless, it should be noted that the measure of interoceptive memory was taken after participants had eaten the snack. This was unavoidable since asking about levels of hunger and satiety prior to the snack may have influenced their consumption. However, taking this measure after the snack means we cannot rule out the possibility that the differential intake of the two groups somehow influenced their recall of their post-lunch feelings of hunger and satiety.

The results also showed that the effects of the mindful eating strategy were not moderated by the individual's level of interoceptive awareness. Again, this is consistent with the view that the effects of the strategy are not mediated by perceptions of hunger or satiety. However, it should be noted that 43 of the 50 participants included in this analysis could be viewed as having relatively low levels of interoceptive awareness. Thus one might argue that the moderating effects of interoceptive awareness were not tested across the full range of individual variability.

In terms of sensitivity to reward, the results showed that the subscales did not significantly moderate the effects of the mindful eating strategy on food intake, though ΔR^2 values were between 3 and 5% and the reward interest subscale showed a trend towards significance. Thus it is possible that the study was underpowered to detect effects and future research would benefit from employing a larger sample size. This would be particularly important where mindful eating is being used as a weight management strategy as research suggests that higher levels of sensitivity to reward can be associated with a higher BMI (Davis et al., 2007; Davis & Fox, 2008).

Future research should also seek to identify the mechanism underlying the effect of mindful eating on subsequent consumption. Recent work by Cornil and Chandon (2016) suggests it may work by prompting individuals to eat a smaller amount in order to maximise sensory pleasure (as opposed to satiety) which research shows tends to peak with smaller portions. Alternative explanations are that it works by weakening associations between conditioned stimuli (e.g., sight and smell of food) and reinforcement (i.e. pleasure associated with food consumption; Treanor, 2011), or by priming dietary restraint.

It would also be important to establish whether the reductions in intake generalise to outside the laboratory setting. In particular it is possible that participants may compensate for their reduced food intake during later periods. In the present study we refrained from asking individuals to avoid eating between the lunch and snack sessions since we believed this might have alerted them to the true aims of the study. As such some individuals did eat between sessions and this seemed to occur more frequently in the experimental group compared to the control group (5 versus 2 participants respectively). This raises the possibility that, for some individuals, the mindfulness strategy may have prompted additional food intake. It would be important to examine this more carefully in future research to determine whether the mindful eating strategy reduces intake in some individuals but increases it in others. As such, future studies exploring the effects of mindful eating outside the laboratory, over longer periods of time, are essential to more clearly establish the utility of this strategy for weight management.

Acknowledgments

We would like to express our thanks to Tina Forster for assistance with the heartbeat perception task and to Philip Corr for advice on the RST-PQ.

Funding Sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

Conflicts of interest: none

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