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

3

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

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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

69
70 Mindful eating can be described as a “non-judgmental awareness of physical and emotional
71 sensations associated with eating” (Framson et al., 2009). Elements of mindful eating are
72 increasingly being incorporated into interventions designed to facilitate weight loss and manage
73 obesity-related eating behaviours (Olsen & Emery, 2015). Although such interventions are often
74 associated with improvements in eating behaviours and weight management, the extent to which
75 these effects are driven by mindful eating is unclear (Olsen & Emery, 2015; O’Reilly, Cook,
76 Spruijt-Metz, & Black, 2014; Tapper, 2017).

77 The current study takes just one aspect of mindful eating, attending to the sensory properties
78 of food, and examines its effects on eating in a more controlled laboratory setting. Previous research
79 using this type of strategy has failed to find any immediate effect on food intake i.e. while the
80 strategy is being applied (Bellisle & Dalix, 2001; Cavanagh, Vartanian, Herman, & Polivy, 2014;
81 Long, Meyer, Leung, & Wallis, 2011). Other studies, however, have found that focusing on the
82 sensory properties of food is associated with reduced food intake at a later point (Arch et al., 2016;
83 Cavanagh et al., 2014; Higgs & Donohoe, 2011). For example, Higgs and Donohoe (2011)
84 examined the effect of focusing on the sensory properties of lunch on cookie consumption 2 to 3
85 hours later among female participants. Results showed that those who were asked to focus on the
86 sensory properties of their lunch consumed fewer cookies (a difference of 27 grams) in comparison
87 to those who ate lunch while reading an article about food or those who ate lunch without any
88 manipulation. Similar results were also attained by Robinson, Kersbergen, and Higgs (2014),
89 whereby overweight and obese female participants who focused on the sensory properties of their
90 food during lunch showed a 30 % reduction in consumption of an afternoon snack (equivalent to
91 106 calories).

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

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

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

124 Research has also shown that individuals with a higher sensitivity to reward tend to be more
125 responsive to appetising foods and food cues (Tapper, Pothos, & Lawrence, 2010), show an
126 increased tendency to overeat (Davis et al., 2007) and consume more fat in their diet (Tapper,
127 Baker, Jiga-Boy, Haddock, & Maio, 2015). As such, participants high in sensitivity to reward may
128 be inclined to eat appetizing foods irrespective of their level of satiety. Thus again we may find that
129 the mindful eating strategy is less effective at reducing intake of a highly palatable snack amongst
130 those with higher sensitivity to reward. For this study a relatively new measure of reward sensitivity
131 was employed; The Reinforcement Sensitivity Theory Personality Questionnaire (RST-PQ; Corr &
132 Cooper, 2016). This measure was selected as it addresses some of the problems with previous
133 measures and better aligns with recent revisions to Reward Sensitivity Theory (Corr, 2016; Corr &
134 Cooper, 2016). The RST-PQ includes four subscales relating to reward sensitivity: (1) reward
135 interest; openness to trying new experiences that are potentially rewarding, (2) goal drive
136 persistence; maintenance of motivation especially when reward is not available immediately, (3)

137 impulsivity; tendency to display behaviour that may lack consideration of consequences, and (4)
138 reward reactivity; feelings of pleasure and emotional ‘highs’ associated with the experience of
139 reward. Because previous studies have found effects with different reward sensitivity subscales
140 (Davis et al., 2007; Tapper et al., 2010; Tapper et al., 2015) and because the subscales in the RST-
141 PQ do not map directly onto those used in previous studies, the effects of each subscale were
142 examined in an exploratory fashion.

143 **Methods**

144 **Participants**

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

156 **Experimental design**

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

162 **Test foods**

163 **Lunch.** In order to avoid ceiling effects on measures of memory for lunch items consumed,
164 a range of different foods were given to participants for their lunch. These consisted of: one cheese
165 and tomato sandwich (158 grams, 405 kcal), 5 cherry tomatoes (55 grams, 11 kcal), 5 Ritz crackers
166 (19 grams, 95 kcal), 5 red grapes (30 grams, 20 kcal), 5 green grapes (33 grams, 20 kcal), 4 mini
167 lemon cakes (33 grams, 135 kcal) and 4 mini chocolate cakes (32 grams, 139 kcal). The sandwiches
168 comprised two pieces of wholegrain bread cut into 2 triangles. This was presented alongside the
169 cherry tomatoes, crackers, and grapes on a plate. The cakes were presented in a separate bowl. The
170 meal contained approximately 825 calories in total. The amount of food consumed by each

171 participant was calculated by counting the number of foods eaten as well as weighing the foods
172 individually before and after the participant ate their meal. In addition to the food provided, two
173 participants requested a cup of water, which they were given.

174

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

180

181 **Audio clip**

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

189

190 **Heartbeat perception task**

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

205

206
$$1 - \frac{\text{actual heartbeats} - \text{counted heartbeats}}{\text{actual heartbeats}}$$

207

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

212

213 Questionnaires

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

219

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

229

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

234

235 A coding scheme was created to score participant memory of (1) quantity of each type of
236 food consumed (e.g. 4 grapes) and (2) details of food consumed (i.e. type of cake and colour of
237 grapes). In total, participants were offered the following 5 foods for lunch: 1 cheese and tomato
238 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

239 participant had eaten only 1 sandwich, 2 tomatoes, 3 crackers, and 7 grapes, they received a score of
240 4 if they listed 1 sandwich, 2 tomatoes, 3 crackers, and 7 grapes, but a score of 3 if they listed 1
241 sandwich, 1 tomato, 3 crackers, and 7 grapes. For analysis purposes, the score received was divided
242 by the overall number of food items (a value between 0-5) consumed by the participant.

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

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

254

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

266

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

270

271 **Procedure**

272 The study was divided into two sessions: the lunch session and the snack session. Upon

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

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

302

303 **Sample size calculation and statistical analysis**

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

307 80% power and 5% alpha a sample size of 28 participants per group would be needed to detect a
308 significant effect. In order to allow for attrition, an additional 2 participants were recruited in each
309 group.

310 Prior to parametric analysis, data were screened for normality. Interoceptive memory for
311 hunger and interoceptive memory for fullness were both positively skewed and so square root
312 transformations were applied. Memory vividness was negatively skewed. Since this was not
313 corrected by transformations, these data were analysed using non-parametric tests. Outliers (defined
314 as >3.5 SDs from the mean) were excluded from relevant parametric analyses. Two-way between
315 subjects anova tests were used to examine the effects of condition and gender on lunch and snack
316 intake. The independent variables were condition (experimental, control) and gender (male, female)
317 whilst the dependent variable was the lunch/snack consumed in calories. Hierarchical regression
318 analyses were used to determine whether interoceptive awareness and sensitivity to reward
319 moderated the effects of condition on snack intake. In step 1, condition and gender were entered.
320 Interoceptive awareness, or the subscales of sensitivity to reward, were then entered at step 2, and
321 the interaction term was entered at step 3. A 2(condition) x 2(memory type) mixed anova was used
322 to examine the effect of condition on interoceptive memory (hunger and fullness). A Mann-
323 Whitney U test was used to test for group differences in memory vividness and independent t-tests
324 were used to test for group differences in memory for lunch items consumed, as well as differences
325 in snack intake between participants who correctly and incorrectly remembered details of food
326 consumed. Chi square was used to determine the relationship between condition and participant
327 memory of details of foods consumed. Pearson's correlation was used to examine whether snack
328 intake was associated with participant interoceptive memory and with memory of quantity of lunch
329 items consumed; Spearman's rho was used to measure the association between snack intake and
330 memory vividness. The statistical analysis package employed was IBM SPSS Statistics (version
331 22).

332

333

Results

334 Participant characteristics

335 Seven participants were excluded from the analysis for the following reasons: 6 guessed that
336 food intake was being assessed (3 experimental, 3 control) and 1 misunderstood instructions
337 (experimental). This left a total of 51 participants; 26 in the experimental condition and 25 in the
338 control condition. (Note that due to these exclusions the sample size was smaller than our target
339 sample size.) As shown in Table 1, these two groups were well matched on a range of relevant
340 characteristics, with the exception of gender, for which there were slightly more females in the

341 control condition compared to the experimental condition. Hunger and fullness were both rated as
 342 relatively low, suggesting that participants considered themselves neither very hungry nor very full
 343 and/or were using the scales conservatively. Importantly, the hunger ratings showed a significant
 344 decline following lunch, whilst the fullness ratings showed a significant increase, indicating that
 345 participants were employing these scales in a meaningful way.

346
 347 **Table 1.** Characteristics of study participants as a function of condition

Characteristic	Experimental (<i>n</i> = 26*)	Control (<i>n</i> = 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)

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

349

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

353

354 **Effect of the mindfulness strategy on snack intake**

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

358

359

360 **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)

361

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

371

372 **Effect of interoceptive awareness on strategy efficacy**

373 Prior to analysis, one outlier in the control group was removed from the data set. The mean
 374 score for participant level of interoceptive awareness was 0.69 ($SD = 0.19$). As noted previously,
 375 other researchers have suggested that a score above 0.85 indicates high interoceptive awareness
 376 whilst a score of 0.85 or lower indicates low interoceptive awareness. According to these criteria,
 377 43 participants in the current study had low levels of interoceptive awareness, and 7 had high levels.
 378 As shown in Table 3, neither interoceptive awareness ($R^2 \Delta = 0.10\%, p = 0.85$) nor the interaction
 379 between interoceptive awareness and condition ($R^2 \Delta = 0.30\%, p = 0.69$) significantly predicted
 380 snack intake. These results indicate that level of interoceptive awareness did not influence the
 381 amount of snack participants consumed nor did it moderate the effects of the mindfulness
 382 manipulation on consumption.

383

384

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

	<u>Snack intake</u> 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	

387

388 * $p < .05$ 389 ** $p < 0.01$ 390 ^acontrol = 0 experimental = 1391 ^bfemales = 0 males = 1

392

393 **Effect of sensitivity to reward on strategy efficacy**

394 The mean scores for participant level of reward interest, goal drive persistence, impulsivity
 395 and reward reactivity were 20.31($SD = 3.82$), 22.57 ($SD = 4.16$), 20.55 ($SD = 4.92$) and 30.20 ($SD =$
 396 4.55) respectively. As shown in Table 4, overall sensitivity to reward did not have a main effect on

397 snack intake ($R^2 \Delta = 9.40\%$, $p = 0.18$). The subscales of goal drive persistence, impulsivity, and
 398 reward reactivity also showed no interaction with condition, ($R^2 \Delta = 2.50\%$, $p = 0.19$; $R^2 \Delta = 3.00$
 399 $\%$, $p = 0.15$; $R^2 \Delta = 2.90\%$, $p = 0.16$ respectively) though the subscale of reward interest showed a
 400 trend toward an interaction ($R^2 \Delta = 4.90\%$, $p = 0.06$).

401

402 **Table 4.** Linear regression models examining the main and moderating effects of reward reactivity
 403 (RR), reward interest (RI), impulsivity (I) and goal drive persistence (GDP) on snack intake (n =
 404 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

431	R^2		0.40	
432	ΔR^2		0.03	
433				
434	Step 3			
435	Constant	293.31	105.96	
436	IM x condition	6.93	4.74	0.87
437	R^2		0.40	
438	ΔR^2		0.03	
439				
440	Step 3			
441	Constant	331.31	121.15	
442	RR x condition	7.31	5.07	1.27
443	R^2		0.40	
444	ΔR^2		0.03	

446 * $p < .05$

447 ** $p < 0.01$

448 ^acontrol = 0 experimental = 1

449 ^bfemales = 0 males = 1

450

451 Interoceptive memory

452 The untransformed data showed that participants in the control group had slightly better
 453 interoceptive memory for hunger and fullness after lunch respectively (mean = 0.44, SD = 0.52;
 454 mean = 0.39, SD = 0.31, n = 25) compared to those in the experimental group (mean = 0.75, SD =
 455 1.22; mean = 0.61, SD = 0.49, n = 26). However, statistical analysis of the square root transformed
 456 data showed no main effect of condition, $F(1, 49) = 1.71, p = 0.20$ and no interaction between
 457 condition and memory type $F(1, 49) = 0.00, p = 0.95$. These results fail to support the hypothesis
 458 that the effects of mindful eating on subsequent consumption are brought about by enhanced
 459 interoceptive memory. Additionally, there was no significant correlation between memory of
 460 hunger and calories of snack consumed ($r = 0.03, p = 0.85$) or between memory of fullness and
 461 calories of snack consumed ($r = -0.17, p = 0.24$), suggesting that more accurate interoceptive
 462 memory of hunger and fullness was not associated with reduced food intake.

463

464

465 Memory vividness

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

473

474 Memory for quantity of food consumed.

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

488

489 Memory for type of food consumed.

490 Participants who did not eat any grapes or cake were excluded from this analysis, leaving a
491 total of 46 participants for the analysis of grape colour (24 experimental, 22 control) and 39 for the
492 analysis of cake type (21 experimental, 18 control). The number of participants in the experimental
493 and control groups who correctly and incorrectly remembered the colour of grapes and type of cake
494 they had eaten are presented in Table 5. Analysis indicated that there was no significant association
495 between condition and memory for details of grape colour ($X\text{-squared}(1) = 0.76$, $p = 0.38$, or
496 between condition and memory for details of cake type ($X\text{-squared}(1) = 2.20$, $p = 0.14$). Thus
497 participants in both the experimental and control groups remembered grape colour and cake type

498 equally well, failing to support the hypothesis that participants in the experimental group would
 499 have a better memory for the details of the food they had consumed.

500

501 **Table 5.** Number of participants in the experimental and control groups who correctly and
 502 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

503

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

513

514

Discussion

515 The results showed that, compared to those in a control condition, participants who ate their
 516 lunch while focusing on the sensory properties of their food consumed fewer biscuits two hours
 517 later. On average, the difference in intake was equivalent to 18.40 grams or 91 calories,
 518 representing a reduction of 45 %. These results are in line with previous research conducted by
 519 Higgs and Donohoe (2011) and Robinson et al. (2014), who found reductions in afternoon snack
 520 intake averaging 27 grams (51%) and 106 calories (30 %) respectively among participants who
 521 focussed on the sensory properties of their food whilst eating lunch. The current study extends this
 522 research by employing a sample that includes males as well as females. Although the small sample
 523 sizes prevent us from concluding that the manipulation was equally effective irrespective of gender,

524 the means suggest that the reductions in intake were not restricted to females (see Table 2). Further
525 research, with a larger sample, would help establish whether gender moderates the relative efficacy
526 of this manipulation. Additionally, although, not an aim of the current study, the fact that the results
527 failed to show a significant difference in lunch intake between the two groups (i.e. whilst the
528 strategy was being applied) is consistent with other research that has failed to find any immediate
529 effects of this strategy (Bellisle & Dalix, 2001; Cavanagh et al., 2014; Long et al., 2011).

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

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

555 The current study extended previous research by also looking at interoceptive memory (i.e.
556 memory for hunger and fullness), but again failed to find any difference between the experimental
557 and control conditions. Thus, despite the fact that previous research has shown that memory plays a

558 role in food consumption (Higgs, 2002; Higgs, Williamson, & Attwood, 2008), the results of the
559 current study suggest that this is unlikely to be the primary mechanism responsible for reduced food
560 intake among those who have attended to the sensory properties of their food during a previous
561 meal. Nevertheless, it should be noted that the measure of interoceptive memory was taken after
562 participants had eaten the snack. This was unavoidable since asking about levels of hunger and
563 satiety prior to the snack may have influenced their consumption. However, taking this measure
564 after the snack means we cannot rule out the possibility that the differential intake of the two groups
565 somehow influenced their recall of their post-lunch feelings of hunger and satiety.

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

572 In terms of sensitivity to reward, the results showed that the subscales did not significantly
573 moderate the effects of the mindful eating strategy on food intake, though ΔR^2 values were between
574 3 and 5% and the reward interest subscale showed a trend towards significance. Thus it is possible
575 that the study was underpowered to detect effects and future research would benefit from
576 employing a larger sample size. This would be particularly important where mindful eating is being
577 used as a weight management strategy as research suggests that higher levels of sensitivity to
578 reward can be associated with a higher BMI (Davis et al., 2007; Davis & Fox, 2008).

579 Future research should also seek to identify the mechanism underlying the effect of mindful
580 eating on subsequent consumption. Recent work by Cornil and Chandon (2016) suggests it may
581 work by prompting individuals to eat a smaller amount in order to maximise sensory pleasure (as
582 opposed to satiety) which research shows tends to peak with smaller portions. Alternative
583 explanations are that it works by weakening associations between conditioned stimuli (e.g., sight
584 and smell of food) and reinforcement (i.e. pleasure associated with food consumption; Treanor,
585 2011), or by priming dietary restraint.

586 It would also be important to establish whether the reductions in intake generalise to outside
587 the laboratory setting. In particular it is possible that participants may compensate for their reduced
588 food intake during later periods. In the present study we refrained from asking individuals to avoid
589 eating between the lunch and snack sessions since we believed this might have alerted them to the
590 true aims of the study. As such some individuals did eat between sessions and this seemed to occur
591 more frequently in the experimental group compared to the control group (5 versus 2 participants

592 respectively). This raises the possibility that, for some individuals, the mindfulness strategy may
593 have prompted additional food intake. It would be important to examine this more carefully in
594 future research to determine whether the mindful eating strategy reduces intake in some individuals
595 but increases it in others. As such, future studies exploring the effects of mindful eating outside the
596 laboratory, over longer periods of time, are essential to more clearly establish the utility of this
597 strategy for weight management.

598

599

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602

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606

607

Conflict of Interest

608 Conflicts of interest: none

609

610

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