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“What time is my next meal?” Delay-discounting individuals choose smaller portions under conditions of uncertainty

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### Abstract

‘Dietary’ delay discounting is typically framed as a trade-off between immediate rewards and long-term health concerns. Our contention is that prospective thinking also occurs over shorter periods, and is engaged to select portion sizes based on the interval between meals (inter-meal interval; IMI). We sought to assess the extent to which the length of an IMI influences portion-size selection. We predicted that delay discounters would show ‘IMI insensitivity’ (relative lack of concern about hunger or fullness between meals). In particular, we were interested in participants’ sensitivity to an uncertain IMI. We hypothesized that when meal times were uncertain, delay discounters would be less responsive and select smaller portion sizes. Participants ( $N=90$ ) selected portion sizes for lunch. In different trials, they were told to expect dinner at 5pm, 9pm, and either 5pm or 9pm (uncertain IMI). Individual differences in future-orientation were measured using a monetary delay-discounting task. Participants chose larger portions when the IMI was longer ( $p < .001$ ). When the IMI was uncertain, delay-discounting participants chose smaller portions than the average portion chosen in the certain IMIs ( $p < .05$ ). Furthermore, monetary discounting mediated a relationship between BMI and smaller portion selection in uncertainty ( $p < .05$ ). This is the first study to report an association between delay discounting and IMI insensitivity. We reason that delay discounters selected smaller portions because they were less sensitive to the uncertain IMI, and overlooked concerns about potential future hunger. These findings are important because they illustrate that differences in discounting are expressed in short-term portion-size decisions and suggest that IMI insensitivity increases when meal timings are uncertain. Further research is needed to confirm whether these findings generalise to other populations.

38 **Keywords:** Chaotic eating, Impulsivity, Delay discounting, Meal planning, Portion size

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## Introduction

Impulsivity is a multidimensional construct that can be measured in various ways (Ewenden, 1999; Whiteside & Lynam, 2016). Delay discounting is a facet of impulsivity, referring to the tendency to respond to the immediate rather than the long-term consequences of a decision (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). It is considered a behavioural-economic index of impulsive decision-making (MacKillop et al., 2011). A non-future oriented individual who discounts delayed rewards is often described as a ‘steep’ delay discounter. Steep temporal discounting has been related to an unhealthy diet, overeating, and obesity (Barlow, Reeves, McKee, Galea, & Stuckler, 2016; Kulendran et al., 2014; Manwaring, Green, Myerson, Strube, & Wilfley, 2011; Rollins, Dearing, & Epstein, 2010). Nevertheless, associations are often weak and unreliable (Appelhans et al., 2011; Eisenstein et al., 2015; Hendrickson, Rasmussen, & Lawyer, 2015; Leitch, Morgan, & Yeomans, 2013; Rasmussen, Lawyer, & Reilly, 2010; Stoeckel, 2013; Stojek, Fischer, Murphy, & MacKillop, 2014; Weller, Cook, Avsar, & Cox, 2008).

One explanation for these inconsistencies is that delay discounting can have multiple effects on food decisions. By contrast, the role of temporal discounting is often framed around a single proposition; that impulsive people overeat because they discount long-term health consequences (Zhang & Rashad, 2008). For example, associations between discounting and overconsumption are often attributed to a lack of concern for future weight gain (Barlow, et al., 2016). This perspective stands at odds with research in both humans (Gregorios-Pippas, Tobler, & Schultz, 2009; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2008; Tanaka et al., 2004) and non-human animals (Mazur, 2001; Shelley, 1993), which shows that temporal discounting operates over much shorter delays of seconds and minutes. Recent studies have found that humans also discount the value of food and drink at intervals as short as thirty seconds (Hendrickson & Rasmussen, 2013; Lumley, 2016;

64 Rasmussen, et al., 2010). This indicates that people also discount short-term consequences of  
65 dietary decisions, rather than just long-term concerns about health or weight gain. In the  
66 present study we considered the prospect that dietary discounting occurs over an intermediate  
67 time frame (hours rather than years) and is evident in the selection of portion sizes from one  
68 meal to the next.

69 The majority of meals are planned in advance – people tend to select a portion to eat  
70 and then clean their plate (Fay et al., 2011; Wilkinson et al., 2012). Portion size is often  
71 governed by the ‘expected satiety’ of a food – a concern to select an amount that is sufficient  
72 to stave off hunger (the desire to eat) in the interval between meals (Brunstrom & Rogers,  
73 2009; Brunstrom, Shakeshaft, & Scott-Samuel, 2008). Anticipated meals timings probably  
74 influence these decisions. However, no studies have systematically explored this  
75 phenomenon and it remains unclear how monetary delay discounting relates to meal planning  
76 in this context. To address these questions we explored the extent to which the length of an  
77 inter-meal interval (IMI) influences lunchtime portion-size selection.

78 One possibility is that meal planning might be less evident in steeper discounters.  
79 People plan their behaviours by evaluating the future consequences of a decision (da Matta,  
80 Gonçalves, & Bizarro, 2012). However, impulsive decision-makers may fail to consider all  
81 relevant information before making a choices (Verplanken & Sato, 2011). Given this logic,  
82 we anticipated that steep delay discounters would be less concerned with the relative  
83 consequences of a long or short IMI when making in-the-moment portion-size judgements.  
84 Therefore, we reasoned that steep discounters would show ‘IMI insensitivity’, (a relative lack  
85 of concern for potential hunger or fullness during the IMI) and have a smaller difference  
86 between portion sizes chosen at a short and long IMI.

87 In addition, we are interested in the effects of an uncertain IMI. Traditionally, a  
88 Westernised meal pattern comprises three primary meals; breakfast, lunch, and dinner.

89 However, sometimes the IMI is uncertain. Recently, there has been an increase in ‘chaotic  
90 eating’ - snacking and eating meals at different times on different days (Samuelson, 2000;  
91 Warde & Yates, 2016). Irregular eating is associated with having a higher BMI (Sierra-  
92 Johnson et al., 2008) and is thought to be a contributing factor to high-energy intake and  
93 weight gain (Berg & Forslund, 2015; Murata, 2000). Unsurprisingly, various dimensions of  
94 impulsivity have been associated with chaotic eating behaviours, including opportunistic  
95 snacking and a preference for snack foods (Fay, White, Finlayson, & King, 2015;  
96 Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010).

97         One possibility is that irregular meal times encourage impulsive behaviours because  
98 they generate uncertainty. Uncertainty has been shown to increase delay discounting;  
99 individuals discount future rewards more steeply when the delayed event is perceived to be  
100 more risky or less certain (Baumann & Odum, 2012; Green & Myerson, 2010; Patak &  
101 Reynolds, 2007). It is important to mention that these studies manipulated the likelihood of  
102 an event occurring, rather than uncertainty around the exact timing of an event. We propose  
103 that uncertainty about the timing of an event may also increase discounting. When IMIs are  
104 certain, individuals can make predictions about future hunger or satiety. However, when  
105 event timings are variable, it is harder to plan for the future (Greville & Buehner, 2010). On  
106 this basis, uncertainty may increase discounting of information about future meal timings. To  
107 protect against the potential for hunger, individuals who are sensitive to the future might  
108 select larger portions when the IMI is uncertain. Conversely, steep discounters may be less  
109 responsive. Hence, we hypothesized that when meal timings were uncertain, steep delay  
110 discounters would select portion sizes that are smaller the average of those chosen when meal  
111 times were certain. We considered evidence for this hypothesis by systematically  
112 manipulating the certainty of an IMI.

113           In the present study we measured portion selection in response to information about  
114 the IMI. Participants chose lunch portions in three different conditions; two where the IMI  
115 was ‘certain’ (dinnertime at 5pm and 9pm), and one where the IMI was ‘uncertain’  
116 (dinnertime at either 5pm or 9pm). To measure individual differences in future-oriented  
117 decision-making we used a standard monetary delay-discounting task. Our primary  
118 hypothesis was that information about future meal timings would influence portion selection  
119 at lunchtime. Specifically, we predicted that portion sizes would differ in each of the three  
120 conditions and that participants would select smaller portions with a certain short IMI,  
121 compared to a certain long IMI. Second, we proposed that steep money discounting would be  
122 associated with IMI insensitivity in both certain and uncertain conditions. When the IMI was  
123 certain, we hypothesized that steep discounters would show a smaller difference between  
124 portions chosen at 5pm and 9pm. When the IMI was uncertain, we expected steep discounters  
125 to select smaller portion sizes than the average of those chosen when meal times were certain.  
126 Finally, to explore how BMI relates to future-oriented decision-making, we assessed  
127 relationships between BMI, portion size, and monetary delay discounting.

128

129 **Method**

130 *Participants:* Participants ( $N= 90$ ; 61 females, 29 males) had a mean age of 21.2y ( $SD = 4.7$ )  
131 and were healthy staff or undergraduate and postgraduate students at the University of  
132 Bristol, recruited through our laboratory volunteer database or as part of a course  
133 requirement. They received either £5 (Sterling) or course credits in remuneration for their  
134 assistance. The protocol was approved by the local Faculty of Science Human Research  
135 Ethics Committee. *A priori*, we thought it was crucial that participants were familiar with the  
136 foods we were including in the experiment. Therefore, we excluded fifteen participants who  
137 indicated eating either of the test foods either 'never', or 'less than once a year'. A further  
138 five participants were excluded for selecting the minimum portion of chow mein (20 kcal) for  
139 lunch, in every condition. We suspect this reflects a technical error or otherwise a problem in  
140 understanding the requirements of the tasks. Six participants had missing data for the delay-  
141 discounting task due to a technical error. In these cases, values were entered as missing data.  
142 The final dataset comprised 70 participants (46 females, 24 males), with a mean age of 21.0  
143 years ( $SD = 4.2$ ), and a mean BMI = 21.68 kg/m<sup>2</sup> ( $SD = 2.6$ ; range = 16.6 - 27.1). In total, 7  
144 participants were underweight, 55 participants were lean and 8 were overweight.

145

146 *Food images:* Based on previous research (Brunstrom, Collingwood, & Rogers, 2010) we  
147 selected two different dishes that are commonly consumed as main meals in the UK: chicken  
148 chow mein and chicken tikka masala with rice. For each dish, we photographed a series of  
149 50 images with portion sizes ranging from 20 kcal to 1000 kcal, in equal 20-kcal steps. The  
150 images were taken using a high-resolution digital camera under identical lighting conditions.  
151 The meals were photographed on the same white plate (255-mm diameter).

152



153 *Measures*

154 *Liking:* Participants were shown a 400-kcal portion of the two test foods in a random order.

155 In each trial they responded on a 7-point scale with end anchor points labelled ‘extremely  
156 dislike’ and ‘extremely like.’

157 *Familiarity:* Familiarity was assessed using a food-frequency questionnaire. Again,  
158 participants were shown a 400-kcal portion of each food. In turn, they responded to the  
159 question ‘How often do you eat this meal?’ by selecting one of the following options; ‘never,’  
160 ‘less than once a year,’ ‘yearly,’ ‘every 2-3 months,’ ‘monthly,’ ‘weekly,’ or ‘daily.’ These  
161 were coded 1-7 (least to most familiar).

162 *Appetite:* Measures of hunger and fullness were obtained using a 100-mm visual-analogue  
163 rating scale headed ‘How [hungry/full/thirsty] do you feel right now?’, with end anchor  
164 points ‘not at all’ and ‘extremely.’ All ratings were elicited on a computer.

165 *TFEQ:* Dietary behaviour was assessed using a computerised version of the 51-item Three  
166 Factor Eating Questionnaire (TFEQ; (Stunkard & Messick, 1985). The instrument contains  
167 36 items with a yes/no response format, 14 items on a 1-4 response scale and one vertical  
168 rating. The relevant items were scored and aggregated into two scales. We were interested in  
169 the Restraint and Disinhibition subscales. ‘Cognitive restraint’ (conscious control of food  
170 intake to control body weight) and ‘disinhibition’ (loss of control over intake). Respectively,  
171 higher scores indicate greater cognitive restraint and disinhibition. Internal-consistency  
172 reliability coefficients (Cronbach’s  $\alpha$ ) were found to be above 0.70 and below 0.90 (de  
173 Lauzon et al., 2004). The internal-consistency coefficient of the restraint and disinhibition  
174 scales in the current study was 0.89.

175 *BMI:* To assess Body Mass Index (BMI), we measured participant’s height and weight at the  
176 end of the experiment. BMI was calculated from measured weight/height<sup>2</sup>.

177

178 *IMI portion task:* Two food images were presented on a VDU. We chose to use photographic  
179 images as similar computer-based tasks have been shown to predict real food selection  
180 (Pouyet, Cuvelier, Benattar, & Giboreau, 2015; Taylor, Yon, & Johnson, 2014). A fixed  
181 portion (400 kcal) of chicken tikka masala was presented on the right and labelled ‘This meal  
182 for dinner.’ A portion of chow mein was presented on the left and labelled ‘This meal for  
183 lunch.’ The chow mein lunch portion could be increased or decreased by depressing the right  
184 or left arrow-keys, respectively. In each trial the participants responded to the question ‘How  
185 much would you eat for lunch RIGHT NOW if you had to eat all of the food on the right for  
186 dinner at...[time inserted].’ In two of the trials the IMI was ‘certain.’ In one certain trial they  
187 were told to expect their evening meal at 5pm. In the other they were told to expect it at 9pm.  
188 In a third trial the IMI was ‘uncertain’ - they were told to expect the meal at either 5pm or  
189 9pm. Participants completed a total of three trials. The order of the trials was randomised  
190 across participants and each trial started with a randomly selected portion of chow mein.

191 To assess whether participants were more responsive to the uncertain future meal  
192 times, we compared portions selected in the certain and uncertain conditions. The uncertain  
193 IMI is framed around the same time points as the two certain IMIs (5pm and 9pm).  
194 Therefore, the effect of uncertainty can be established by comparing portions chosen in the  
195 uncertain condition with average of the portions chosen in the two certain condition.  
196 Specifically, we used the three selected portion sizes (2 certain trials and 1 uncertain trial)  
197 and computed a value (IMI index score) based on the following calculation: uncertain 5pm or  
198 9pm - (certain 5pm + certain 9pm)/2). This provides a measure of the effect of uncertainty  
199 (relative to certainty) on portion selection. We calculated a separate IMI index score for each  
200 participant. A positive IMI index score indicates that larger portions were chosen in the  
201 uncertain condition than in the average of the two portions selected in the certain conditions.

202

203 *Delay-discounting task:* Delay discounting was measured using a computerised forced-choice  
204 task. The task was an adapted version of one previously introduced by Du and colleagues  
205 (Du, Green, & Muerson, 2016). In a series of trials participants indicated whether they  
206 preferred to receive a hypothetical delayed reward of £100 after a fixed interval (*e.g.*, 1 year)  
207 or a smaller monetary amount immediately. Participants completed several blocks of 10  
208 trials. In every trial the delayed reward was always £100. In the first trial of each block the  
209 immediate reward was half the delayed value (£50). If the participant selected the immediate  
210 reward, it was adjusted down to £16.66 (33.3% of its original value) in the second trial. If the  
211 participant selected the delayed reward then it was adjusted up to £83.33 (the same difference  
212 = £33.33). The same rationale was applied in subsequent trials (trials 3-10). However, in each  
213 trial the adjustment amount decreased by 33.3% (*i.e.*, from £33.33 in trial 2 to £22.22 trial 3,  
214 from £22.21 in trial 3 to £14.81 trial 4, and so on). This single ‘staircase’ approach  
215 progressively converged around a point of indifference in which the delayed and immediate  
216 amounts are equally likely to be selected.

217       Initially, three practice blocks were presented. In order, the hypothetical delays were 2  
218 years, 1 year, and 6 months. This was followed by six further blocks. Each presented a  
219 scenario with one of the following delays; 2 days, 7 days, 30 days, 6 months, 1 year, 2 years.  
220 The order of these blocks was randomised across participants and responses were used to  
221 calculate a measure of delay discounting. The delay-discounting task and the IMI portion task  
222 were implemented using custom software (available on request) written in Visual Basic  
223 (Microsoft version 6.0).

224       Following Myerson et al. (Myerson, Green, & Warusawitharana, 2001), for each  
225 participant, a measure of delay discounting was obtained from area under the curve (AUC)  
226 values derived from the delay-discounting task. AUC values were calculated using the  
227 trapezoid method. Smaller AUC values indicate steeper discounting.

228

229 *Procedure:* Participants completed one 45-minute session between 12pm and 2pm. On arrival  
230 they reported how long ago they last ate and then rated their appetite and thirst. They then  
231 completed the IMI portion task, followed by liking and familiarity ratings, and then the delay-  
232 discounting task. Finally, participants completed the TFEQ and we measured their BMI. At  
233 the end of the study the participants were debriefed and thanked for their assistance.

234

235 *Data analysis:* First, to determine whether portion-size selection was influenced by  
236 information about the IMI, we conducted a one-way, repeated-measures ANCOVA with  
237 three conditions (portion size when the IMI was short, long and uncertain). We included  
238 gender as a between-subjects factor and BMI and age as covariates. A paired *t*-test was used  
239 to evaluate specific differences across participants between portion sizes chosen in the long  
240 and short certain conditions. Second, to measure sensitivity to change in length of the certain  
241 IMI, we assessed the difference between portions chosen in the two certain conditions. This  
242 allowed us to calculate a Pearson's correlation to explore how certain IMI sensitivity related  
243 to monetary delay discounting. Similarly, we calculated the correlation between delay  
244 discounting and sensitivity to the uncertain IMI, relative to the certain IMIs (IMI index  
245 score). In addition, we assessed correlations between BMI and both IMI index score and  
246 delay discounting.

247

248 Post-hoc analyses were conducted to investigate whether individual differences in  
249 delay discounting mediated the relationship between BMI and portion-size selection in  
250 uncertain IMIs. For a mediating relationship to be confirmed, four key criteria must be met.  
251 Criterion 1, the independent variable (IV) and the dependent variable (DV) must be  
252 significantly associated (Baron & Kenny, 1986). Criterion 2, the IV and the mediator must be  
significantly associated; Criterion 3, the mediator and the DV must be significantly

253 associated; Criterion 4, when the mediator is controlled for in a regression of the IV on the  
 254 DV, the  $\beta$ -value relating the IV to the DV becomes insignificant. In our post-hoc analysis, we  
 255 entered the IMI index scores as the IV, BMI as the DV, and impulsivity as the mediator.

256 All four criterion were explored using multiple regression analysis. The  
 257 unstandardized regression coefficients and standard errors of the relationship between the IV  
 258 and the mediator, and between the DV and the mediator, are used to calculate the path  
 259 coefficient ( $b_{ab}$ ) and its standard error ( $^s b_{ab}$ ). The path coefficient is divided by the standard  
 260 error to give a  $t$ -ratio. If the  $t$ -ratio exceeds  $\pm 1.96$ , then the indirect path is significant and a  
 261 mediating relationship is confirmed. All data were analysed using IBM SPSS statistics  
 262 version 21 (IBM, New York, USA).

## 263 Results

264 *Participant characteristics:* Table 1 shows mean scores for liking, appetite, TFEQ, and  
 265 familiarity, as well as participant characteristics. Both BMI and Delay discounting AUC  
 266 scores were not related to liking, hunger, fullness, familiarity restraint or disinhibition (See  
 267 Table 2). Mean TFEQ-restraint score ( $M = 6.7$ ,  $SD = 3.6$ ) and mean TFEQ-disinhibition score  
 268 ( $M = 6.3$ ,  $SD = 2.6$ ) were all in the low range (Lesdema et al., 2012; Stunkard & Messick,  
 269 1985).

270

271 Table 1. Means and standard deviations (SD) for participant characteristics, questionnaires,  
 272 ratings and delay discounting AUC

Measure (units/range)	Mean (SD)	Range (min-max)
Age (y)	21.0 (4.2)	18.0 – 43.0
BMI (kg/m <sup>2</sup> )	21.7 (2.6)	16.7 – 27.1

TFEQ-restraint (0 - 21)	6.7 (3.6)	1.0 – 17.0
TFEQ-disinhibition (0 - 16)	6.3 (2.6)	1.0 – 13.0
Delay discounting (AUC)	0.6 (0.2)	0.0 – 1.0
Appetite (1-7)	5.0 (1.73)	1.0 – 7.0
Familiarity (chicken tikka and chow mein; (2-14)	9.8 (1.33)	2.0 – 14.0

273 (N = 70; 46 female, 24 male)

274

275 Table 2. Relationships (Pearson's correlations) between inter-meal interval (IMI) index score,  
276 delay discounting area under the curve (DD AUC), TFEQ, BMI, liking, hunger, and fullness.

	1	2	3	4	5	6	7	8
1. IMI index								
2. DD AUC	.29*							
3. TFEQ-Disinhibition	.18	.17						
4. TFEQ-Restraint	-.01	-.03	.13					
5. BMI	-.27*	-.40**	-.16	.29*				
6. Liking	-.20	-.13	-.09	-.11	.04			
7. Fullness	.16	.11	.02	.03	.14	-.07		
8. Hunger	-.139	.051	-.03	-.12	-.08	.11	-.74**	

277 \*  $p < .05$

278 \*\*  $p < .01$

279

280 *IMI portion task:* Our analysis revealed a main effect of IMI on portion selection after  
281 controlling for age, gender and BMI,  $F(2,132) = 4.53, p = .012, \eta^2 = .06$ . Specifically,  
282 participants chose larger portions with a certain long IMI (dinner at 9pm;  $M = 549.1$  kcal,  $SD,$   
283  $205.3$ ) than a short certain IMI (dinner at 5pm;  $M = 423.4$  kcal,  $SD = 217.1$ ),  $t(69) = 6.02, p$   
284  $= .00$ . Covariates, age, gender and BMI did not predict variance in portion selection (all  $p >$   
285  $.05$ ). Correlations between IMI index score and liking, fullness, TFEQ-restraint and TFEQ-  
286 disinhibition failed to reach significance (see Table 2).

287 *Relationship between discounting and IMI sensitivity:* There was a medium sized, but non-  
288 statistically significant, correlation between delay discounting AUC and the difference  
289 between portion size at long and short certain IMIs,  $r(62) = .18, p = .15^1$ . Consistent with our  
290 hypothesis, we found a significant positive correlation between delay discounting AUC and  
291 IMI index score,  $r(62) = .29, p < .05^1$ . Participants who exhibited steeper discounting (lower  
292 AUC) chose smaller portions when the IMI was uncertain than when it was certain (See  
293 Supplemental Material for visual representation of relationship between IMI index and delay  
294 discounting).

295 *Relationship between BMI with discounting and portion size selection at the uncertain IMI:*  
296 There was a significant negative correlation between BMI and IMI index score  $r(69) = -$   
297  $.27, p < .05$ . Individuals with a high BMI chose smaller portions when the IMI was uncertain,  
298 compared to when it was certain. There was also a significant negative correlation between  
299 BMI and delay discounting AUC  $r(62) = -.40, p < .001$ . Participants who showed steeper  
300 discounting had a higher BMI than those with shallower discounting. Relationship between

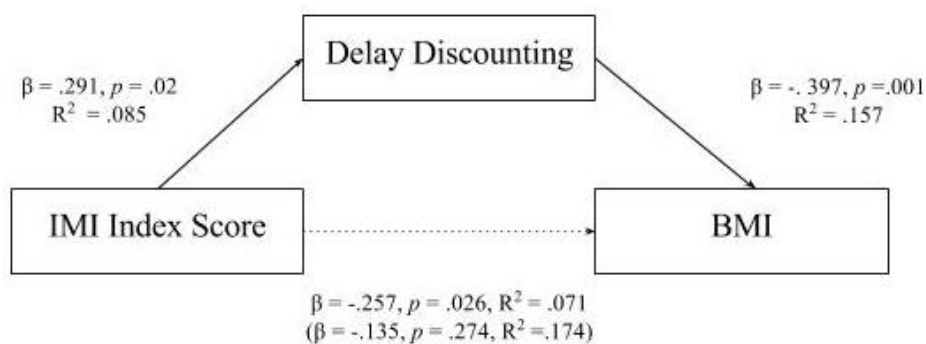
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<sup>1</sup> Degrees of freedom differ due to missing data

301 BMI and inter-meal-interval (IMI) index score. (See Supplemental Material for visual  
 302 representation of relationship between IMI index and BMI).

303

304 *Post-hoc mediation analysis:* Significant relationships were confirmed between IMI index  
 305 score and BMI (criterion 1), between delay discounting AUC and IMI index score (criterion  
 306 2) and between delay discounting AUC and BMI (criterion 3). When delay discounting AUC  
 307 was controlled for in a regression of IMI index score on BMI, IMI index score no longer  
 308 predicted BMI (criterion 4). Figure 1 shows the regression coefficients associated with tests  
 309 of each relationship. Subsequently, the Sobel test (Sobel, 1982) confirmed that the two-tailed  
 310 mediator was significant,  $t(62) = -2.59, p = .012$ . As all criteria for mediation were met and  
 311 the Sobel test was significant, this suggests that delay discounting mediates the relationship  
 312 between BMI and smaller portion size selection at the uncertain, relative to certain, IMI



313

314 *Figure 1.* Delay discounting as a mediator of the relationship between selection of smaller  
 315 portion sizes at the uncertain inter-meal interval (IMI index score) and BMI. Unstandardized  
 316  $\beta, p$  and  $R^2$  values are shown for each relationship. Regression coefficients associated with  
 317 Criterion 4 (when the mediator is controlled for in a regression of IMI index score on delay  
 318 discounting) are shown in brackets.



319

320 *Post-hoc power calculation:* To assess satisfactory statistical power, we conducted a post hoc  
321 power analysis. The medium effect size states that we were underpowered to detect an  
322 association between delay discounting and the difference between portion sizes selected at  
323 the certain IMIs. The calculation revealed a sample size of 240 would be required to detect  
324 this effect with an  $\alpha$  of 0.05 and a  $1-\beta$  of 0.80.

325

326

### Discussion

327 This study assessed how information about IMIs influences portion size decisions and  
328 whether steep delay discounters respond differently to the predictability of an IMI. Our  
329 primary hypothesis was that information about future IMIs would influence portion size  
330 decisions. Secondly, we hypothesised that steep monetary delay discounters would be less  
331 sensitive to information about the duration of the certain IMIs, and show a small differences  
332 between portions selected in the long and short IMIs. In particular, we predicted steep  
333 discounters would show even greater disregard for future meal times in the uncertain IMI.

334 Consistent with our first hypothesis, participants chose larger portions in response to  
335 the certain long IMI than in response to the certain short IMI. This is the first demonstration  
336 that people use information about future meal timings to make in-the-moment decisions about  
337 how much to eat. Greater monetary delay discounting was associated with smaller portion  
338 selection in response to the uncertain IMI, compared to the average of those chosen in the  
339 certain IMIs. We suggest that shallow discounters selected larger portions to protect against  
340 possible hunger during the IMI. Consistent with our hypothesis, steep delay discounters  
341 appeared to show a disregard for the uncertain IMI, possibly due to a lack of concern for  
342 potential hunger between meals. However, steep and shallow discounters selected similar  
343 portion sizes when the IMI was certain, suggesting that delay discounting is less relevant

344 when an IMI is known. Consistent with this idea, individuals show greater discounting of a  
345 future reward when the occurrence of a delayed event is less certain (Baumann & Odum,  
346 2012; Green & Myerson, 2010; Patak & Reynolds, 2007). Our results suggest that variability  
347 in the timing of the event also increases discounting. In the future, researchers should  
348 differentiate between irregular eating in the presence or absence of uncertainty. These  
349 observations suggest that dietary discounting is more likely to be expressed when meal times  
350 are uncertain. Hence, a distinction between certain and uncertain meal timings might be  
351 helpful, especially in studies seeking to understand relationships between chaotic eating,  
352 discounting, and BMI.

353 We also predicted that steep discounters would be less likely to plan their meals based  
354 on the duration of the certain IMI. In line with this, delay discounting was associated with a  
355 smaller difference between portions selected at the long and short certain IMIs. This suggests  
356 that steep discounters were less sensitive to information about future meal timings, whereas  
357 future-oriented individuals were more likely to plan for the IMI. Although this relationship  
358 failed to reach statistical significance, the effect sizes indicate a small-to-medium sized  
359 association, suggesting that the current study was potentially underpowered (a sample size of  
360 240 would be required to detect this effect, with an  $\alpha$  of 0.05 and a  $1-\beta$  of 0.80).

361 Temporal discounting is generally regarded as a trait that promotes overconsumption.  
362 Our data show that delay discounting might actually reduce self-selected portion size.  
363 Specifically, the expression and downstream effects of discounting might depend upon  
364 whether a meal is planned and whether an IMI is certain or uncertain. These findings could  
365 help to explain previous inconsistent associations between delay discounting and eating  
366 behaviour. Dietary discounting is typically conceptualised as a trade-off between immediate  
367 food reward and long-term future health costs. Our data suggests that discounting is also  
368 expressed in shorter-term delays from one meal to the next. These distinctions are subtle yet

369 potentially essential, and are generally overlooked in studies exploring the acute effects of  
370 temporal discounting on food intake. A more nuanced understanding of how meal timings  
371 influence future-oriented decisions will contribute to the development of an evidence base,  
372 which can inform guidelines around structured eating and meal planning.

373         Our post-hoc analysis suggests that delay discounting mediated a relationship between  
374 having a higher BMI and selecting *smaller* portions with an uncertain IMI. This appears  
375 counterintuitive; steep discounters had higher BMIs, yet chose smaller portions. One  
376 possibility is that a lack of concern for future hunger promotes various compensatory  
377 behaviours, such as the selection of energy-dense snacks between meals. In line with this,  
378 both chaotic eating and impulsivity have been associated with a greater tendency to snack  
379 between meals (Fay, et al., 2015) and also greater consumption of palatable foods (Lumley,  
380 2016). Further research is required to determine whether snacking behaviour is more  
381 prevalent in individuals who less sensitive to information about IMIs.

382         The study may be limited by using computer-based judgements of food decisions.  
383 Nevertheless, our focus was to understand relationships between discounting and meal  
384 planning. Although computer-based portion judgments are shown to be predictive of real  
385 food intake (Pouyet, et al., 2015; Taylor, et al., 2014), it remains to be determined whether  
386 the same relationships might be observed in a study of food intake. This was beyond the  
387 scope of the present study but might be considered in future research. Additionally, as  
388 participants were university students with a relatively narrow range of BMIs, the  
389 generalizability of our findings remains unclear. The generalisability of our conclusions that  
390 delay discounters are less sensitive to information about future meal timings are somewhat  
391 limited by the lack of statistical power limited our conclusions; subsequent research is  
392 required to explore these relationships in a larger and more representative sample. Finally, as

393 mood is shown to influence delay discounting (Koff & Lucas, 2011), subsequent studies  
394 could assess how mood influences decision-making regarding discounting of meal timings.

395

### 396 *Concluding remarks*

397 In summary, steep delay discounters selected smaller portions in response to an  
398 uncertain IMI, compared to the certain IMIs. We reasoned that in conditions of uncertainty,  
399 non-future oriented individuals were less concerned with potential hunger or fullness between  
400 meals and selected how much they would like in the moment. These results suggest that delay  
401 discounting is more likely to be expressed in a ‘chaotic’ eating environment. Future studies  
402 are required to assess these relationships in a wider sample and with real food intake to  
403 improve generalizability of our conclusions. Our findings merit consideration because they  
404 demonstrate how short-term discounting can influence portion-size decisions.

405

406

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### **Conflict of interest.**

414 The authors declare no conflict of interest.

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