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Accepted Manuscript

A dual-process psychobiological model of temperament predicts liking and wanting for food and trait disinhibition

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1 Title: A dual-process psychobiological model of temperament predicts liking and wanting for
2 food and trait Disinhibition

3

4 Running title: Temperament and Food Reward

5

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29

30 **Title**

31

32 A dual-process psychobiological model of temperament predicts liking and wanting
33 for food and trait Disinhibition

34 **Abstract**

35

36 A dual-process model of temperament, incorporating the Behavioural Inhibition
37 System (BIS), Behavioural Activation System (BAS) and effortful control (EC), may
38 help to predict hedonic responses to palatable food and trait disinhibition. **PURPOSE:**
39 This study aimed to determine if the BIS, BAS and EC predicted liking and wanting
40 for high-fat, sweet foods in adults with overweight and obesity, and if collectively,
41 these variables predicted the eating behaviour trait of Disinhibition. **METHODS:** 168
42 adults (104 females, mean BMI = 33.3 kg/m²) completed the Three Factor Eating
43 Questionnaire, the Carver and White BIS/BAS scales, the Adult Temperament
44 Questionnaire-Effortful Control Scale – Short Form and the Leeds Food Preference
45 Questionnaire. The strength of the BIS, BAS and EC in predicting wanting and liking
46 for high-fat sweet foods, and trait Disinhibition was assessed using hierarchical
47 multiple regression. **RESULTS:** Both the BIS and EC predicted liking, $F(6, 161) =$
48 $5.05, p < .001, R^2 = .16$, and EC inversely predicted wanting, $F(6, 161) = 3.28, p =$
49 $.005, R^2 = .11$. The BIS, EC and liking predicted, $F(8, 159) = 11.0, p < .001, R^2 =$
50 $.36$, and explained 36% of Disinhibition. The BAS did not predict wanting, liking or
51 Disinhibition. **CONCLUSIONS:** These results demonstrate that a sensitive BIS and a
52 lower level of effortful control predicts food reward and Disinhibition in overweight
53 and obese adults. Consequently, interventions that aim to increase effortful control
54 and reduce BIS reactivity may be beneficial for reducing hedonically motivated,
55 disinhibited eating behaviour.

56

57 **Keywords:** Behavioural Inhibition System; Behavioural Activation System; effortful
58 control; Disinhibition; wanting and liking; eating behaviour; obesity; temperament.

59 Introduction

60

61 The high prevalence of overweight and obesity in developed and developing
62 countries represents a threat to global public health (Shmidt Morgan & Sorensen,
63 2014). Easy access to highly palatable and energy dense food, within an obesogenic
64 environment, has contributed to this prevalence (Berthoud, 2012; Shmidt Morgan &
65 Sorensen, 2014; Stubbs & Lee, 2004; Swinburn & Egger, 2002; Swinburn et al.,
66 2011). Within this environment, high levels of emotional, binge and disinhibited
67 eating behaviour lead to less successful weight management outcomes after
68 intervention, whether the intervention is delivered via bariatric surgery or dietary
69 prescription (Blair, Lewis, & Booth, 1990; Canetti, Berry, & Elizur, 2009; Chesler,
70 2012; Dodsworth, Warren-Forward, & Baines, 2010; Elfhag & Rössner, 2005;
71 Kayman, Bruvold, & Stern, 1990; McGuire, Wing, Klem, Lang, & Hill, 1999; Ohsiek
72 & Williams, 2011; Poole et al., 2005; Teixeira et al., 2010; Wing et al., 2008; Wing &
73 Phelan, 2005). The factors that lead to higher levels of disinhibited eating behaviour
74 and a failure to lose or maintain weight loss in some but not others appear to reflect
75 individual differences in fundamental biological and psychological processes
76 (Blundell & Finlayson, 2004; Dalton & Finlayson, 2014; Davis, 2009).

77 Trait Disinhibition, as measured by The Three Factor Eating Questionnaire
78 Disinhibition scale (Stunkard & Messick, 1985), is a construct that describes an
79 individual's disposition towards opportunistic eating behaviour (Bryant, King, &
80 Blundell, 2008). It contains items that measure emotional eating (Stunkard &
81 Messick, 1985) and has been associated with binge eating behaviours, obesity and
82 BMI (Bryant et al., 2008; French, Epstein, Jeffery, Blundell, & Wardle, 2012;
83 Wadden, Foster, Letizia, & Wilk, 1993; Yanovski & Sebring, 1994; Yeomans, 2010;
84 Yeomans & Coughlan, 2009; Yeomans, Tovey, Tinley, & Haynes, 2004). Individuals
85 with higher levels of trait Disinhibition or binge eating behaviour have also been
86 shown to have a greater hedonic response towards the rewarding properties of food
87 (Bryant et al., 2008; Dalton & Finlayson, 2014; Finlayson, Bordes, Griffioen-Roose,
88 de Graaf, & Blundell, 2012).

89 Human appetite is regulated by a synergistic relationship that exists between
90 hedonic and homeostatic drives, which are designed to meet biological needs
91 (Finlayson, King, & Blundell, 2007a). When this relationship is disrupted, the hedonic

92 drive can override homeostatic needs, leading to hedonic eating behaviours that are
93 motivated by a desire to satisfy psychological needs rather than physiological
94 requirements (Finlayson & Dalton, 2012; Lowe & Butryn, 2007). Hedonic eating
95 behaviours can be separated into the psychological components of wanting and liking
96 (Dalton & Finlayson, 2014; Finlayson & Dalton, 2012). Wanting represents the
97 motivational value, desire or craving that is attributed to a highly palatable food item
98 (Dalton & Finlayson, 2013; Finlayson & Dalton, 2012). The anticipated and perceived
99 sensations of pleasure upon consumption and accompanying feelings of positive
100 affect are attributed to liking (Berridge, 1996; Dalton & Finlayson, 2014; Finlayson &
101 Dalton, 2012; Pecina, 2008). If an individual has learnt to consume certain foods for
102 their hedonically rewarding properties (Mela, 2000), enhanced levels of wanting and
103 liking would be expected to contribute towards appetite dysregulation and thence to
104 disinhibited eating behaviour within an obesogenic environment (Davis et al., 2009).

105 Not everyone in an obesogenic environment is susceptible to weight gain, and
106 not all attempts to lose or maintain weight loss result in failure. Research has shown
107 that at least 20% of individuals who attempt weight loss are successful over the longer
108 term (Wing & Hill, 2001; Wing & Phelan, 2005) and that individuals who reduce
109 their levels of emotional and disinhibited eating behaviours are more successful at
110 initial weight loss and the maintenance of this loss over a 12-24 month period
111 (Keranen et al., 2009; Teixeira et al., 2010; Wing & Phelan, 2005). Therefore, in line
112 with the recommendations of previous researchers, it is important to determine
113 whether particular temperament traits characterise individuals with higher levels of
114 hedonic and trait eating behaviours (Davis, 2009; Dietrich, Federbusch, Grellmann,
115 Villringer, & Horstmann, 2014).

116 Rothbart, Derryberry and Posner's (1994) developmental model of temperament
117 offers a novel perspective from which to investigate an individual's phenotypic risk to
118 express higher levels of hedonically-motivated, trait eating behaviour. It describes
119 how an interaction between an individual's level of innate emotional reactivity, and a
120 later developing capacity to regulate it, gives rise to temperament and trait behaviour
121 (Derryberry & Rothbart, 1997). This model can be conceptualised within a dual-
122 process model of self-regulation (Carver, Johnson, & Joorman, 2009). Within this
123 framework an individual's capacity to regulate underlying 'bottom-up' emotional
124 reactivity within Reinforcement Sensitivity Theory's (RST) Behavioural Activation

125 System (BAS) (Gray, 1987a, 1987b) and Behavioural Inhibition System (BIS) (Gray,
126 1982), is determined by the over-arching, ‘top-down’, self-regulatory, attentional
127 process of effortful control (Bijttebier, Beck, Claes, & Vandereycken, 2009; Carver,
128 2008; Carver, Johnson, & Joorman, 2008; Claes, Robinson, Muehlenkamp, &
129 Vandereycken, 2010; Derryberry & Rothbart, 1997; Müller, Claes, Wilderjans, & de
130 Zwaan, 2014; Rothbart & Bates, 2006).

131 Within Gray and McNaughton’s revised RST (Gray & McNaughton, 2000),
132 activation within the affective-motivational systems of the BIS, Fight-Flight-Freeze
133 System (FFFS) and BAS elicit corresponding states of physiological and emotional
134 arousal and behaviour when an individual interacts with their environment.
135 Activation within the BAS generates positive emotions such as hope, and motivates
136 approach behaviours (Corr, 2008), whilst BIS and FFFS activation generate the
137 negative emotions of anxiety and fear respectively, and motivate avoidance
138 behaviours (Corr, 2008). The BIS and the FFFS represent independent systems in the
139 revised RST (Gray & McNaughton, 2000). However, both systems can be
140 encompassed within an overarching factor that is sensitive to punishment (Corr, 2004,
141 2008). Therefore, within this research, the BIS and FFFS will be referred to as a
142 single BIS factor throughout this paper.

143 In the temperament and eating behaviour field, BAS sensitivity has been
144 assumed to promote approach behaviours in response to cues of reward, such as
145 highly palatable food (Davis, 2009; Davis et al., 2007). Furthermore, an individual’s
146 hedonic response, tendency to binge eat and to use food as an affect regulation
147 strategy, is currently believed to rest on their predisposition towards a high level of
148 sensitivity to reward (i.e., BAS sensitivity) (Aldao, Nolen-Hoeksema, & Schweizer,
149 2010; Davis, 2009; Dawe & Loxton, 2004). Therefore, when individuals with higher
150 levels of BAS sensitivity experience negative affect, due to the conceptualisation that
151 they are highly susceptible to the rewarding properties of high-fat sweet foods (Davis
152 et al., 2009; Davis & Loxton, 2014; Davis et al., 2007; Davis, Strachan, & Berkson,
153 2004; Dawe & Loxton, 2004; Stice, Spoor, Ng, & Zald, 2009), the literature suggests
154 that they will turn to the use of these foods as a maladaptive affect regulation strategy
155 (Aldao et al., 2010; Davis, 2013).

156 An individual’s propensity to seek food-based rewards to regulate affect, could
157 also arise from a high level of BIS sensitivity that is not effectively regulated by the

158 attentional process of effortful control. Within Rothbart, Derryberry and Posner's
159 (1994) developmental approach to temperament the attentional process of effortful
160 control determines an individual's capacity to regulate the intensity of their current
161 emotional state and to override habitual behaviours in order to engage in goal-directed
162 actions (Rothbart, Ellis, & Posner, 2010). However, one's capacity to exert effortful
163 control over their emotions and subsequent behaviours, stems from a limited
164 attentional resource, which could be fatigued by a reactive BIS (Baumeister, Vohs, &
165 Tice, 2007; Rueda, Posner, & Rothbart, 2010). It has been suggested that a sensitive
166 BIS and lower levels of effortful control could increase vulnerability to the experience
167 of psychopathological states such as anxiety and depression (Bijttebier et al., 2009);
168 moreover, research has shown that this combination of factors predicts general
169 distress (Dinovo & Vasey, 2011). Therefore, an individual with a sensitive BIS and a
170 low level of effortful control may be vulnerable to unregulated negative affect
171 (Derryberry & Rothbart, 1997; Gross, 2013; Rothbart, Sheese, & Posner, 2013;
172 Wallace & Newman, 1997).

173 The possibility that an individual with a high level of BIS reactivity that is not
174 effectively regulated may be vulnerable to negative affect is particularly relevant to
175 understanding an individual's susceptibility towards disinhibited eating behaviour
176 because high-fat sweet foods are often consumed for their affect relieving properties
177 (Gibson, 2006; Macht, 2008). Carver (2009) has shown that BIS sensitivity is
178 positively correlated to feelings of relief and higher levels of BIS sensitivity and
179 lower levels of effortful control have been linked to emotion dysregulation,
180 difficulties regulating emotions, psychological impairment, disordered eating,
181 emotional eating, and eating in the absence of hunger, in obese pre-bariatric
182 participants and obese inpatients, (Müller et al., 2014; Schäfer et al., 2017). Therefore,
183 it is possible that similarly to BAS sensitive individuals, BIS sensitive individuals,
184 with lower levels of effortful control, could also seek out high-fat sweet foods for
185 their rewarding properties. However, no known studies have as yet explored the
186 relationship between BIS/BAS sensitivity, effortful control, wanting and liking and
187 trait Disinhibition within a community sample.

188 The present study aimed to explore whether a dual-process model of
189 temperament predicted the psychological processes of wanting and liking for high-fat,
190 sweet foods, and in turn, trait Disinhibition, within an overweight and obese

191 community-based sample. It was hypothesised that high levels of BIS and BAS
192 sensitivity, and a low level of effortful control, would predict greater wanting and
193 liking for high-fat sweet foods and that collectively, these factors would predict trait
194 Disinhibition.

195

196 **Materials and methods**

197

198 **Participants**

199 184 adult male and female participants were recruited from university and
200 community settings across metropolitan and regional areas to take part in a study
201 investigating the influence of temperament on food reward and eating behaviour. The
202 inclusion criterion was a BMI of greater than 25 kg/m². Exclusion criteria included
203 intellectual or physical impairment, an eating disorder, being pregnant or up to 12
204 months post-partum or breastfeeding, and being a smoker. These criteria were
205 presented to participants in recruitment flyers and information-consent forms for self-
206 screening and subsequently checked in the data files prior to analysis.

207

208 **Procedures**

209

210 Individuals who expressed an interest responded via email to the lead
211 researcher. Participants were then provided with a hyperlink to the study
212 questionnaires administered on a secure online platform. Questionnaire data were
213 collected electronically by the use of the Key Survey web-based survey management
214 system (WorldApp Key Survey, 2018). Participants attended an assessment session
215 within two weeks of completing the online questionnaires, to complete the measure of
216 liking and wanting (Leeds Food Preference Questionnaire, LFPQ) and to measure
217 height and weight. The LFPQ was administered electronically and data was collected
218 at the in-person session using the experimental software E-prime (v.2.10.242 (200),
219 Psychology Software tools, ND). Undergraduate students received course credit for
220 participation and all participants were offered the opportunity to enter a raffle to win
221 one of two AUD\$50.00 gift vouchers.

222 Research procedures were reviewed and approved by Queensland University
223 of Technology's Human Research Ethics Committee. Participants provided written
224 informed consent.

225

226 Measures

227 *The BIS/BAS Scales* (Carver & White, 1994) were used to measure the degree of
228 sensitivity or reactivity within Gray's Behavioural Inhibition System (BIS) and
229 Behavioural Activation System (BAS) (Gray, 1976, 1982, 1987b). The BIS/BAS
230 scales (Carver & White, 1994) are a 20-item likert scale measure which assesses
231 behavioural inhibition or sensitivity to punishment, and behavioural approach or
232 sensitivity to reward, by measuring an individual's emotional responses or reactions
233 to harmful or rewarding scenarios (Carver & White, 1994). The BIS/BAS scales have
234 demonstrated acceptable convergent validity, discriminant validity (Carver & White,
235 1994; Jorm et al., 1999) and stability, with test re-test reliability reported over an 8
236 month period from .62 to .92 (Kasch, Rottenberg, & Arnow, 2002). The structural
237 validity of the scales has been supported by confirmatory factor analyses (Campbell-
238 Sills, Liverant, & Brown, 2004; 1994; Gomez & Gomez, 2005; Heubeck, Wilkinson,
239 & Cologon, 1998) and the BIS and BAS scales have shown acceptable internal
240 consistency (Carver & White, 1994; Cooper, Perkins, & Corr, 2007; Davis et al.,
241 2007; Dietrich et al., 2014). Gray's original RST was revised in 2000 by Gray and
242 McNaughton (Gray & McNaughton, 2000). The Carver and White BIS scale, which
243 was developed to measure Gray's original RST contains items that measure both
244 FFFS and BIS activation and negative affect (Carver & White, 1994; Corr, 2004,
245 2008; Heym, Ferguson, & Lawrence, 2008). Therefore, total BIS scores describe
246 activation within the BIS and/or the FFFS, and activation within either system is taken
247 to represent an overarching factor of sensitivity to punishment (Corr, 2004). The
248 BIS/FFFS factors are referred to as the one BIS factor throughout this paper.

249 *The 19-item Effortful Control Scale - short form* (EC) is a subscale from the
250 Adult Temperament Questionnaire (ATQ) (Evans & Rothbart, 2007) that assesses a
251 higher-order factor of temperament defined by an individual's capacity to exert
252 control over their behaviour and emotions as they interact with their environment. It
253 consists of three scales measuring attentional control (EC-ATT), inhibitory control
254 (EC-INH), and activation control (EC-ACT). Construct validity of the EC has been

255 supported by exploratory factor analysis (Evans & Rothbart, 2007). Internal
256 consistency has been demonstrated for the EC total score (Bridgett, Oddi, Laake,
257 Murdock, & Bachmann, 2013; Zhang et al., 2015), which was used in this research.

258 *The 51-item Three Factor Eating Behaviour Questionnaire (TFEQ)* (Stunkard
259 & Messick, 1985) is designed to measure eating behaviour in relation to the following
260 three dimensions: Disinhibition (TFEQ-D), Restraint (TFEQ-R) and Hunger (TFEQ-
261 H). The 16-item Disinhibition Scale, which measures a loss of control over food
262 intake, was used in this study. The Disinhibition scale has more recently been defined
263 as a measure of trait behaviour that describes the opportunistic eating behaviour of an
264 individual with a readiness to eat (Bryant et al., 2008). The Disinhibition scale (16
265 items) measures a loss of control over food intake (e.g. “Do you go on eating binges
266 though you are not hungry?”) and scores range from 0 to 16, with 16 representing the
267 highest level of Disinhibition. Acceptable test-retest reliability over a 1-month period
268 and predictive validity and internal consistency have been demonstrated (Dietrich et
269 al., 2014; Stunkard & Messick, 1985).

270 *Liking and wanting for High Fat Sweet Foods.*

271 *The Leeds Food Preference Questionnaire (LFPQ)* (Finlayson, King, &
272 Blundell, 2007, 2008) is a validated, computerised, behavioural task, which measures
273 explicit liking and implicit wanting for specific dimensions of food using
274 photographic images. This computerised task has been used extensively in other
275 research (Dalton & Finlayson, 2014; Finlayson et al., 2012; Finlayson, Bryant,
276 Blundell, & King, 2009; Verschoor, Finlayson, Blundell, Markus, & King, 2010) and
277 is described in more detail elsewhere (Dalton & Finlayson, 2014; Finlayson et al.,
278 2008). The photograph images are categorised according to fat (high or low) and taste
279 (sweet or savoury). To measure explicit liking participants were asked to rate “*How*
280 *pleasant would it be to taste some of this food now?*” on 100 points visual analogue
281 scales. To measure implicit wanting participants were presented with 96 pairs of
282 foods and asked to select their most wanted food by responding as quickly and as
283 accurately as possible to the prompt “*Which food do you most want to eat now?*”
284 Reaction times were measured to provide a covert indication of the implicit
285 motivational value of the food images. Reaction times for all responses were recorded
286 and adjusted by both the speed and frequency in which a food category was either
287 selected or avoided, to provide a mean response time for each food type. A positive

288 score indicates a more rapid preference for a particular food category and a negative
289 score indicates the opposite. A zero score indicates that the category is equally
290 preferred, when compared to others in the task. Scores have been reported as ranging
291 from -100 – 100, with a typical mean of 0 and a SD of 25 (Dalton & Finlayson, 2014).
292 Levels of explicit liking and implicit wanting for high-fat sweet foods are reported in
293 the present study. High-fat sweet foods were investigated as their intake has been
294 linked to a behavioural phenotype with a demonstrated susceptibility towards
295 overconsumption (Dalton & Finlayson, 2014). Psychometrically, the LFPQ has
296 acceptable test-retest reliability measured using immediate repetition and up to one
297 week later (Finlayson, Arlotti, Dalton, King, & Blundell, 2011). This measure is a
298 good predictor of food choice both in the laboratory and the field, and is sensitive to
299 individual differences in trait eating behaviours (Dalton & Finlayson, 2014) .

300

301 Data analyses

302 Data were analysed using SPSS (IBM SPSS Statistics for Windows, Version
303 22.0, Armonk, NY: IBM Corp, released 2013). Continuous variables are presented as
304 means (*M*) and standard deviations (*SD*). Hierarchical linear multiple regression
305 (HLMR) assessed the strength of the BIS, BAS and effortful control total scale (EC-
306 T) to predict implicit wanting (IW_HFSW) and explicit liking of high-fat
307 (EL_HFSW) sweet foods and the strength of the BIS, BAS, ECT-T, IW_HFSW and
308 EL_HFSW to predict Disinhibition. An α -level of 0.05 was used to determine
309 statistical significance for all analyses.

310

311 **Results**

312 A total of 184 participants completed the online questionnaires. Data for
 313 thirteen individuals were incomplete and not included in the analyses. A further case
 314 was excluded as she reported breast-feeding and a final case was removed due to a
 315 BMI of 66, which was 3 *SD* above the mean. The additional results of one individual
 316 were omitted as they did not complete the in-person session to assess LFPQ. Thus, the
 317 sample consisted of the remaining 168 individuals (104 females and 64 males, 8%
 318 students, age range 18 to 65 years). All relevant assumptions were met for parametric
 319 analyses, except as indicated. Descriptive statistics are presented in Table 1. Means,
 320 standard deviations and bivariate correlations between Disinhibition, Temperament
 321 and wanting and liking for high-fat sweet foods are provided in Table 2

322 Table 1.

323 Mean and SD characteristics (n = 168)

Variable	<i>M</i>	<i>SD</i>
Age	45.88	12.16
BMI	33.26	6.79
BIS	21.39	3.69
BAS	38.86	5.77
EC-T	86.61	13.85
D	9.17	3.82
IW_HFSW	0.21	31.99
EL_HFSW	42.30	23.51

325 BMI: Body Mass Index (kg/m²); IW_HFSW: Implicit wanting high-fat sweet;
 326 BIS: Behavioural Inhibition System; BAS: Behavioural Activation
 327 System; EC-T: Effortful Control Total Scale; D: Disinhibition Scale; IW_HFSW: Implicit wanting high-fat sweet;
 328 EL_HFSW: Explicit liking high-fat sweet
 329

330 There were significant positive correlations between the BIS and wanting and
 331 liking for high-fat sweet foods, and significant negative correlations between effortful
 332 control and wanting and liking for high-fat sweet foods. Similarly, there were
 333 significant positive correlations between Disinhibition and the BIS and between
 334 wanting and liking for high-fat sweet foods and significant negative correlations
 335 between Disinhibition and effortful control. There were no significant correlations
 336 between the BAS and any of the following variables: Disinhibition, effortful control
 337 and wanting and liking for high-fat sweet foods (Table 2).

338 Table 2.
 339 Means, standard deviations, and bivariate correlations between Disinhibition, BIS,
 340 BAS, effortful control, and wanting and liking for high-fat sweet foods (n = 168)

Variables	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
1. D	9.17	3.81	---					
2. BIS	21.4	3.69	.39**	---				
3. BAS	38.9	5.75	-.014	-.009	---			
4. EC-T	86.5	13.9	-.40**	-.35**	-.107	---		
5. IW_HFSW	0.21	32.0	.33**	.18*	.012	-.27**	---	
6. EL_HFSW	42.3	23.5	.35**	.24**	-.060	-.30**	.71**	---

D: Disinhibition Scale; BIS: Behavioural Inhibition System; BAS: Behavioural Activation System; EC-T: Effortful Control Total Scale; IW_HFSW: Implicit Wanting high-fat sweet; EL_HFSW: Explicit liking high-fat sweet
 * $p < .05$, ** $p < .01$

341

342 The first regression analysis assessed the prediction of implicit wanting for
 343 high-fat sweet foods (IW_HFS) by the BIS, BAS and EC-T. Table 3 displays the
 344 unstandardized regression coefficients (*B*), the standardized regression coefficients
 345 (β) for the final model after the third step, and R^2 and R^2 change after each step.

346 When controlling for age, gender and BMI at step 1, the addition of BIS and
 347 BAS, in step 2 explained an additional 2.8% of the variance in IW_HFSW. However,
 348 this step was not significant, F change (2, 162) = 2.47, $p = .088$. Closer inspection
 349 revealed that the BIS ($\beta = .18$, $p = .031$) but not the BAS ($\beta = .042$, $p = .59$) was a
 350 unique predictor. The addition of EC-T in step 3 explained an additional 3.7% of the
 351 variance in IW_HFSW, F change (1, 161) = 6.73, $p = .01$. This final model was
 352 significant, F (6, 161) = 3.28, $p = .005$ and explained 11% of the variance in
 353 IW_HFSW. In the final model, a lower level of EC-T was the strongest predictor of
 354 IW_HFSW ($\beta = -.21$, $p = .01$) followed by BMI ($\beta = .17$, $p = .035$). After the addition
 355 of EC-T, the BIS became non-significant ($\beta = .10$, $p = .24$), suggesting that EC-T
 356 fully mediated the effects of the BIS to predict IW_HFSW.

357

358

359 Table 3
 360 Hierarchical multiple regression analysis predicting implicit wanting for high-fat
 361 sweet foods ($N = 168$)

Step and predictor variable	B	$SE B$	β	R^2	R^2
Step 1:				.043	
Age	-0.087	0.20	-.033		
Gender	-0.33	5.37	-.005		
BMI	0.78	0.37	.17*		
Step 2:				.072	.028
BIS	0.87	0.73	.10		
BAS	0.059	0.43	.011		
Step 3:				.11*	.037*
EC-T	-0.49	0.19	-.21*		

BMI: Body Mass Index (kg/m^2), BIS: Behavioural Inhibition System, EC-T: Effortful Control Total Scale

B : unstandardised coefficient; β : standardised coefficient. Gender coded as 0 = female.

* $p < .05$, ** $p < .01$

362
 363 The second regression assessed the prediction of explicit liking of high-fat
 364 sweet foods (EL_HFSW) by the BIS, BAS and EC-T (Table 4). Table 4 displays the
 365 unstandardized regression coefficients (B), the standardized regression coefficients
 366 (β) for the final model after the third step, and R^2 and R^2 change after each step.

367

368 Table 4
 369 Hierarchical multiple regression analysis predicting explicit liking for high-fat sweet
 370 foods ($N = 168$)

Step and predictor variable	B	$SE B$	β	R^2	ΔR^2
Step 1:				.030	
Age	-0.26	0.14	-.13		
Gender	7.60	3.83	.16		
BMI	0.31	0.26	.088		
Step 2:				.11**	.080**
BIS	1.35	0.52	.21*		
BAS	-0.25	0.31	-.061		
Step 3:				.16**	.048**
EC-Total	-0.41	0.13	-.24**		

BMI: Body Mass Index (kg/m^2); BIS: Behavioural Inhibition System; EC-T: Effortful Control Total Scale;

B : unstandardised coefficient; β : standardised coefficient. Gender coded as 0 = female.

* $p < .05$, ** $p < .01$, *** $p < .001$

371

372 When controlling for age, gender and BMI at step 1, the addition of the BIS and
 373 BAS in step 2 explained an additional 8% of the variance in EL_HFSW, F change (2,
 374 162) = 7.27, p = .001. Closer inspection revealed that the BIS (β = .30, p < .001) but
 375 not the BAS (β = -.025, p = .74) was a unique predictor. The addition of EC-T, in step
 376 3, explained an additional 4.8% of the variance in EL_HFSW, F change (1, 161) =
 377 9.26, p = .003). The final model was statistically significant, F (6, 161) = 5.05, p <
 378 .001, and explained 16% of the variance in explicit liking for high-fat sweet foods. A
 379 lower level of EC-T was the strongest predictor of EL_HFSW (β = -.24, p = .003)
 380 followed by higher BIS (β = .21, p = .011) and the male gender (β = .16, p = .038)

381 The final regression assessed the prediction of trait Disinhibition by the BIS,
 382 BAS, EC-T, IW_HFSW and EL_HFSW (Table 5).

383

384 Table 5

385 Hierarchical multiple regression analysis of variables predicting Disinhibition (N =
 386 168)

Step and predictor variable	B	$SE B$	β	R^2	ΔR^2
Step 1:				.15***	
Age	0.012	.020	.040		
Gender	-1.60	.56	-.21**		
BMI	0.10	.038	.19**		
Step 2:				.25***	.092***
BIS	0.18	.076	.18*		
BAS	-0.012	.044	-.018		
Step 3:				.31**	.060**
EC-T	-0.057	.020	-.21**		
Step 4:				.33*	.028*
IW_HFSW	0.003	.011	.024		
Step 5:				.36*	.022*
EL_HFSW	0.037	.016	.23*		

BMI: Body Mass Index (kg/m^2); BIS: Behavioural Inhibition Scale; BAS: Behavioural Activation Scale; EC-T: Effortful Control Total Scale; IW_HFSW: Implicit wanting high fat sweet; EL_HFSW: Explicit liking high fat sweet; B: unstandardised coefficient; β : standardised coefficient. Gender coded as 0 = female.

* p < .05; ** p < .01; *** p < .001

387

388 When controlling for age, gender and BMI at step 1, the addition of BIS and
389 BAS in step 2 explained an additional 9.2% of the variance in Disinhibition, F change
390 (2, 162) = 9.89, $p < .001$. At this step the BIS ($\beta = .32$, $p < .001$) but not the BAS ($\beta =$
391 $.05$, $p = .906$) predicted Disinhibition. The addition of EC-T in step 3, the addition of
392 IW_HFSW in step 4 and the addition of EL_HFSW in the final fifth step all explained
393 an additional 6%, F change (1, 161) = 14.0, $p < .001$, 2.8%, F change (1, 160) = 6.72,
394 $p = .01$, and 2.2% of the variance in Disinhibition, F change (1, 159) = 5.48, $p = .05$,
395 respectively. The final model was significant, F , (8, 159) = 11.0, $p < .001$, and
396 explained 36% of the variance in disinhibited-eating behaviour. Explicit liking for
397 high-fat sweet foods was the strongest predictor of disinhibited-eating behaviour ($\beta =$
398 $.23$, $p = .021$), followed by a lower level of EC-T ($\beta = -.21$, $p = .004$), female gender
399 ($\beta = -.21$, $p = .005$), greater BMI ($\beta = .19$, $p = .005$) and higher BIS ($\beta = .18$, $p =$
400 $.018$).

401

402 Discussion

403

404 A dual-process model of temperament predicted the psychological processes of
405 wanting and liking for high fat sweet food, and in turn, trait Disinhibition, within an
406 overweight and obese community-based sample.

407 The BIS and a lower level of effortful control predicted the explicit liking of
408 high-fat sweet foods, and collectively the BIS, a lower level of effortful control and
409 greater liking contributed to the prediction of trait Disinhibition. It was conceptualised
410 that a sensitive BIS would be related to wanting and liking for high fat sweet foods.
411 However, the manner in which the BIS contributes towards these food reward
412 processes, which have been linked to over-consumption, weight gain and obesity
413 (Dalton & Finlayson, 2013, 2014), is currently unknown. Enhanced levels of
414 psychological reward are capable of overriding homeostatic appetite and disinhibiting
415 intake (Dalton & Finlayson, 2013; Finlayson & Dalton, 2012). Whilst a sensitive BAS
416 has been implicated in an individual's hedonic response to food and their resultant
417 eating behaviour (Aldao et al., 2010; Davis & Carter, 2009; Davis & Fox, 2008; Davis
418 et al., 2007; Davis et al., 2004; Dawe & Loxton, 2004), the literature is yet to
419 investigate whether a sensitive BIS and a low level of effortful control are also linked
420 to enhanced levels of psychological reward.

421 A low level of effortful control appeared to fully mediate the effect of a
422 sensitive BIS to predict the implicit wanting of high-fat sweet foods. It is possible that
423 this finding supports a cognitive model of self-regulatory failure (Heatherton &
424 Wagner, 2011), whereby a high level of BIS reactivity, and an ensuing state of
425 negative affect would be expected to lead to a reduced capacity to employ attentional
426 or effortful control resources.

427 The finding that a sensitive BIS and a low level of effortful control predicted
428 liking for high-fat, sweet foods is informative because it has been suggested that
429 individuals can learn to like foods that have been associated with an improvement in
430 their emotional state (Mela, 2000, 2006). BIS sensitivity has been linked to the
431 experience of negative affective states, such as anxiety and depression (Bijttebier et
432 al., 2009; Zinbarg & Yoon, 2008) and sensitivity within the BIS has been positively
433 correlated to the experience of relief (Carver, 2009). Subsequently, it is plausible that
434 BIS sensitive individuals could have learnt to like high-fat sweet foods for their
435 negative-affect relieving properties; presumably to reduce levels of physiological
436 arousal and psychological distress and to increase feelings of positive affect, calm and
437 relief (Adam & Epel, 2007; Carver, 2009; Dallman, 2010; Gibson, 2006; Macht,
438 2008).

439 BIS sensitivity and a low level of effortful control, but not BAS sensitivity,
440 predicted the psychological rewards of wanting and liking, which in turn predicted
441 trait Disinhibition. Based on the assumptions of Gray's RST, conceptualisation and
442 previous results within the temperament and eating behaviour literature (Davis, 2009;
443 Davis et al., 2009; Davis & Loxton, 2014; Davis et al., 2007; Davis et al., 2004; Dawe
444 & Loxton, 2004; Franken & Muris, 2005; Matton, Goossens, Braet, & Vervaet, 2013;
445 O'Neil et al., 2012), the absence of an effect of the BAS on implicit wanting, explicit
446 liking and Disinhibition was unexpected. However, the absence of a significant
447 relationship between the BAS and Disinhibition is in line with the results of the
448 following studies by Dietrich et al. (2014) and Yeomans and Brace (2015). Whilst, the
449 observed association between the BIS and Disinhibition in the present study, contrasts
450 with the findings of Dietrich et al. (2014),

451 Dietrich et al. (2014) investigated the relationships between eating behaviour
452 (Three Factor Eating Questionnaire Disinhibition scale (TFEQ-D)), BIS/BAS Scale
453 scores and BMI in a sample of 192 healthy males and females with an average age of

454 26.6 years and BMI of 26.7kg/m². Although not a specific focus of this study, neither
455 the BAS nor the BIS were significantly correlated with Disinhibition, $r = 0.13$, (*ns*)
456 and $r = -0.022$ (*ns*), respectively. Yeomans and Brace (2015) investigated whether
457 acute exposure to food stimuli enhanced impulsive responding and risky decision-
458 making in a sample of 96 healthy females (average age 21.4 years and BMI
459 22.6kg/m²) classified with a tendency towards overeating (TFEQ-D), and whether
460 these relationships were related to BIS/BAS scale scores. In this study, a trend for a
461 small positive correlation between the BAS and Disinhibition was observed, $r = 0.20$,
462 ($p = 0.052$), however, a correlation result between the BIS and Disinhibition was not
463 reported.

464 It is possible that a direct association between the BAS and trait Disinhibition
465 was difficult to establish in the current sample because BAS reactivity, as
466 characterised by the BAS scale, may not provide a sensitive measure of trait,
467 opportunistic overeating, i.e. Disinhibition (Bryant et al., 2008) in overweight and
468 obese samples such as the present study and the study by Dietrich et al. (2014). This
469 reasoning is supported by the research findings of O'Neil et al. (2012), who used
470 principal component analysis (PCA) to investigate the relationship between fat mass,
471 eating behaviour and psychological traits in a sample with a similar BMI ($M = 30.5$
472 kg/m², $SD = 4.0$) and age ($M = 41.6$, $SD = 10.3$) to the present study. Their first
473 analysis explored the degree of association and commonality within the eating
474 behavioural questionnaires. This PCA included three measures of eating behaviour
475 and two measures of psychological traits, which included the TFEQ-D and BIS/BAS
476 scales. From this analysis, two significant components emerged to describe the
477 sample: A psychological component that corresponded to reward sensitivity and an
478 eating behaviour component that corresponded to binge/overeating. Within the
479 psychological component, the BAS reward responsiveness subscale was the most
480 strongly correlated of all the BIS/BAS subscales. However, this component was found
481 to be only weakly, negatively correlated to the eating behaviour component.
482 Therefore, these results appear to support the suggestion that in the overweight and
483 obese, reward sensitivity might not be a sensitive measure of tendency towards
484 disinhibited eating.

485 The present study found a positive, significant relationship between the BIS and
486 Disinhibition. This relationship has not been previously described or discussed

487 elsewhere within the literature. It is possible that this could be due to previous studies'
488 recruitment of samples with lower BMI scores (e.g., Dietrich et al., 2014) than the
489 present sample. It is possible that a relationship between the BIS and Disinhibition
490 may only become apparent at higher levels of BMI. The results from a second PCA
491 conducted by O'Neil et al. (2012) support this line of reasoning. The second analysis
492 included the addition of anthropometrical measures of fat free and fat mass and BMI
493 to the behavioural measures. Although not reported upon, closer inspection of the
494 single component that emerged from their second PCA showed that when BMI, fat
495 and fat free mass were added to the analysis, the BIS scale was more highly correlated
496 within this component than the BAS subscales. This suggests that BIS sensitivity was
497 more highly correlated with Disinhibition, fat mass and BMI than BAS sensitivity
498 after the inclusion of these anthropometrical measures. As the study by O'Neil et al.
499 (2012) had a similar BMI to the present sample, this result supports the
500 conceptualisation that a direct relationship between the BIS and Disinhibition may
501 only become apparent at higher levels of BMI.

502 Further evidence to support this line of reasoning is provided as follows: Lower
503 average BMI, Disinhibition and BIS scores were found in the samples of Yeomans
504 and Brace (2015, S1 Dataset) (BMI: 22.6 kg/m², BIS: 11.9, Disinhibition: 6.9) and
505 Dietrich et al. (2014) (BMI: 26.7 kg/m², BIS: 17.0, Disinhibition: 6.1), when
506 compared with that of O'Neil et al. (2012) (BMI: 30.5 kg/m², BIS: 18.6,
507 Disinhibition: 8.7), and the present study (BMI: 33.33 kg/m², BIS: 21.39,
508 Disinhibition: 9.2). When these results are considered from the lowest to the highest
509 level of BMI, they suggest that BIS and Disinhibition scores increase alongside BMI.
510 Therefore, a positive association between the BIS and trait Disinhibition could be
511 difficult to establish in individuals of normal or close to normal levels of body weight.

512 For this same reason, a higher BMI could also have reduced the likelihood of
513 finding a relationship between the BAS and Disinhibition. For example, it has been
514 established that an inverse-U relationship between the BAS and BMI exists in adults,
515 adolescents and children (Davis & Fox, 2008; Dietrich et al., 2014; Verbeken, Braet,
516 Lammertyn, Goossens, & Moens, 2012). Within this relationship, the BAS is
517 positively linked to BMI as it increases to approximately 30kg/m². However, as BMI
518 increases beyond 30kg/m² the relationship becomes negative. This study's findings

519 suggest that individuals with a higher mean BMI might be predisposed to eat in
520 response to BIS sensitivity and not only to BAS sensitivity.

521 Sensitivity within Gray's BAS is currently conceptualised as contributing
522 towards an enhanced motivation for highly palatable foods, craving, over-
523 consumption and "food addiction" (Davis, 2009; Davis et al., 2009; Davis & Loxton,
524 2014; Davis et al., 2007; Davis et al., 2004; Dawe & Loxton, 2004; Franken & Muris,
525 2005). However, this study's results suggest that it is also important to consider an
526 individual's level of BIS as well as their level of BAS sensitivity, and their level of
527 effortful control. Moreover, research undertaken in pre-bariatric candidates, supports
528 the study results. Pre-bariatric participants with higher levels of BIS sensitivity and
529 lower levels of effortful control have higher levels of disordered, emotional, and non-
530 hungry eating behaviours than individuals with lower levels of BIS sensitivity and
531 higher levels of effortful control (Müller et al., 2014; Schäfer et al., 2017).

532 The results of this study differ from and extend the conceptual and empirical
533 basis of the literature. Collectively, these results, which have linked the BIS and a low
534 level of effortful control, but not the BAS, to hedonic, trait eating behaviour, suggest
535 an alternative pathway to disinhibited eating behaviour that is linked to a
536 constitutionally based predisposition to experience more frequent episodes of negative
537 affect (Carver & White, 1994; Corr, 2008; Gable, Reis, & Elliot, 2000). The results
538 imply that a sensitive BIS, in combination with a low level of effortful control, could
539 sensitise an individual to the hedonic properties of food. As sensitivity within the BIS
540 is linked to the experience of negative affect (Carver & White, 1994) *and* relief
541 (Carver, 2009) it is possible that BIS sensitive individuals who possess low levels of
542 effortful control may be less able to regulate their emotions and subsequently seek
543 familiar "liked" high-fat, sweet, comfort type foods for their rewarding and affect
544 relieving properties. As a consequence, they may exhibit higher levels of disinhibited
545 eating behaviour.

546 This research provides novel insight into the relationship between temperament,
547 disinhibited eating behaviour and psychological food reward in a community-based,
548 sample. However, several limitations must be noted. Self-report measures which were
549 used in this study may be susceptible to response shift phenomena where changes in
550 internal conceptualization, priorities and reference standards may have influenced the
551 participant's perception of the traits and states measured (McPhail & Haines, 2010;

552 Sprangers & Schwartz, 1999). These phenomena have been described as particularly
553 relevant for people living with long term conditions (Agborsaangaya, Lau, Lahtinen,
554 Cooke, & Johnson, 2013) such as being overweight or obese. Moreover, as the
555 variables were measured at the one time-point causal links between psychobiological
556 temperaments, eating behaviour and food reward cannot be established. Furthermore,
557 it is noted that the present study had higher mean BIS scores than those reported in
558 O'Neil et al. (2012) who also excluded individuals who suffered from a psychiatric
559 condition whereas this study did not. As the BIS/BAS scales capture an individual's
560 susceptibility to experience anxiety (Carver & White, 1994), the higher BIS scores in
561 this study may also reflect the inclusion of individuals with a diagnosis of anxiety or
562 depression. Subsequently, this study may not generalise to populations where people
563 with psychological comorbidities have been excluded. Finally, this study was
564 conducted in overweight and obese adults with a mean age of 45.88 years (*SD* 12.16)
565 therefore, these findings may not generalise to younger adults with a BMI less than 25
566 kg/m².

567 Further research is required to establish whether the findings from this research
568 can be replicated in an independent sample of overweight and obese adults of similar
569 and younger age. Additionally, research that objectively explores the nature of the
570 links between BIS sensitivity and food reward using a food intake task is
571 recommended. Moreover, this research has implied that the BIS could be linked to
572 psychological food reward and Disinhibition through the use of food as an affect
573 regulation strategy. Therefore, a measure of an individual's capacity to regulate their
574 emotions should also be included. Furthermore, an individuals' capacity to exert
575 effortful control over a reactive temperament, can be strengthened through training
576 (Posner, Rothbart, & Tang, 2015; Tang, Posner, Rothbart, & Volkow, 2015).
577 Therefore, it may be beneficial for future research to explore the effect that additional
578 training in self-regulatory strategies might have on BIS sensitive individuals desiring
579 behaviour change. Effective strategies will either strengthen, conserve or replete
580 stocks of effortful control (Masicampo, Martin, & Anderson, 2014). Finally, it would
581 be valuable to employ a rigorous longitudinal study design to determine the degree of
582 change in BMI over time.

583 In conclusion, the results of this study suggest that, within a dual-process model
584 of temperament, a sensitive BIS and lower levels of effortful control may increase risk

585 of hedonically motivated disinhibited eating behaviour. The temperament model
 586 considered within this research is constitutional (Rothbart et al., 2013): An individual
 587 with a sensitive BIS may never have learnt to effectively manage their level of
 588 emotional reactivity. Therefore, it may be unrealistic to expect individuals who have
 589 learnt to consume highly palatable foods to regulate affect to successfully change their
 590 eating behaviour; unless they are simultaneously taught strategies, which either
 591 strengthen, conserve or replenish their capacity for effortful control.

592

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595

596

597

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