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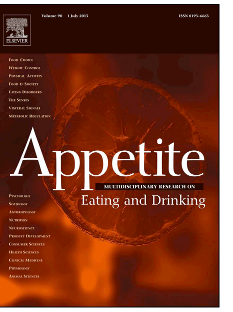

A dual-process psychobiological model of temperament predicts liking and wanting for food and trait disinhibition

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Running title: Temperament and Food Reward

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Title

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

Abstract

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

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

Introduction

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

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

Human appetite is regulated by a synergistic relationship that exists between hedonic and homeostatic drives, which are designed to meet biological needs (Finlayson, King, & Blundell, 2007a). When this relationship is disrupted, the hedonic drive can override homeostatic needs, leading to hedonic eating behaviours that are motivated by a desire to satisfy psychological needs rather than physiological requirements (Finlayson & Dalton, 2012; Lowe & Butryn, 2007). Hedonic eating behaviours can be separated into the psychological components of wanting and liking (Dalton & Finlayson, 2014; Finlayson & Dalton, 2012). Wanting represents the motivational value, desire or craving that is attributed to a highly palatable food item (Dalton & Finlayson, 2013; Finlayson & Dalton, 2012). The anticipated and perceived sensations of pleasure upon consumption and accompanying feelings of positive affect are attributed to liking (Berridge, 1996; Dalton & Finlayson, 2014; Finlayson & Dalton, 2012; Pecina, 2008). If an individual has learnt to consume certain foods for their hedonically rewarding properties (Mela, 2000), enhanced levels of wanting and liking would be expected to contribute towards appetite dysregulation and thence to disinhibited eating behaviour within an obesogenic environment (Davis et al., 2009).

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

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

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

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

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

An individual’s propensity to seek food-based rewards to regulate affect, could also arise from a high level of BIS sensitivity that is not effectively regulated by the attentional process of effortful control. Within Rothbart, Derryberry and Posner's (1994) developmental approach to temperament the attentional process of effortful control determines an individual's capacity to regulate the intensity of their current emotional state and to override habitual behaviours in order to engage in goal-directed actions (Rothbart, Ellis, & Posner, 2010). However, one's capacity to exert effortful control over their emotions and subsequent behaviours, stems from a limited attentional resource, which could be fatigued by a reactive BIS (Baumeister, Vohs, & Tice, 2007; Rueda, Posner, & Rothbart, 2010). It has been suggested that a sensitive BIS and lower levels of effortful control could increase vulnerability to the experience of psychopathological states such as anxiety and depression (Bijttebier et al., 2009); moreover, research has shown that this combination of factors predicts general distress (Dinovo & Vasey, 2011). Therefore, an individual with a sensitive BIS and a low level of effortful control may be vulnerable to unregulated negative affect (Derryberry & Rothbart, 1997; Gross, 2013; Rothbart, Sheese, & Posner, 2013; Wallace & Newman, 1997).

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

The present study aimed to explore whether a dual-process model of temperament predicted the psychological processes of wanting and liking for high-fat, sweet foods, and in turn, trait Disinhibition, within an overweight and obese community-based sample. It was hypothesised that high levels of BIS and BAS sensitivity, and a low level of effortful control, would predict greater wanting and liking for high-fat sweet foods and that collectively, these factors would predict trait Disinhibition.

Materials and methods

Participants

184 adult male and female participants were recruited from university and community settings across metropolitan and regional areas to take part in a study investigating the influence of temperament on food reward and eating behaviour. The inclusion criterion was a BMI of greater than 25 kg/m^2. Exclusion criteria included intellectual or physical impairment, an eating disorder, being pregnant or up to 12 months post-partum or breastfeeding, and being a smoker. These criteria were presented to participants in recruitment flyers and information-consent forms for self-screening and subsequently checked in the data files prior to analaysis.

Procedures

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

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

Measures

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

The 19-item Effortful Control Scale - short form (EC) is a subscale from the Adult Temperament Questionnaire (ATQ) (Evans & Rothbart, 2007) that assesses a higher-order factor of temperament defined by an individual's capacity to exert control over their behaviour and emotions as they interact with their environment. It consists of three scales measuring attentional control (EC-ATT), inhibitory control (EC-INH), and activation control (EC-ACT). Construct validity of the EC has been supported by exploratory factor analysis (Evans & Rothbart, 2007). Internal consistency has been demonstrated for the EC total score (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013; Zhang et al., 2015), which was used in this research.

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

Liking and wanting for High Fat Sweet Foods.

The Leeds Food Preference Questionnaire (LFPQ) (Finlayson, King, & Blundell, 2007, 2008) is a validated, computerised, behavioural task, which measures explicit liking and implicit wanting for specific dimensions of food using photographic images. This computerised task has been used extensively in other research (Dalton & Finlayson, 2014; Finlayson et al., 2012; Finlayson, Bryant, Blundell, & King, 2009; Verschoor, Finlayson, Blundell, Markus, & King, 2010) and is described in more detail elsewhere (Dalton & Finlayson, 2014; Finlayson et al., 2008). The photograph images are categorised according to fat (high or low) and taste (sweet or savoury). To measure explicit liking participants were asked to rate *“How pleasant would it be to taste some of this food now?”* on 100 points visual analogue scales. To measure implicit wanting participants were presented with 96 pairs of foods and asked to select their most wanted food by responding as quickly and as accurately as possible to the prompt *“Which food do you most want to eat now?”* Reaction times were measured to provide a covert indication of the implicit motivational value of the food images. Reaction times for all responses were recorded and adjusted by both the speed and frequency in which a food category was either selected or avoided, to provide a mean response time for each food type. A positive score indicates a more rapid preference for a particular food category and a negative score indicates the opposite. A zero score indicates that the category is equally preferred, when compared to others in the task. Scores have been reported as ranging from -100 – 100, with a typical mean of 0 and a SD of 25 (Dalton & Finlayson, 2014). Levels of explicit liking and implicit wanting for high-fat sweet foods are reported in the present study. High-fat sweet foods were investigated as their intake has been linked to a behavioural phenotype with a demonstrated susceptibility towards overconsumption (Dalton & Finlayson, 2014). Psychometrically, the LFPQ has acceptable test-retest reliability measured using immediate repetition and up to one week later (Finlayson, Arlotti, Dalton, King, & Blundell, 2011). This measure is a good predictor of food choice both in the laboratory and the field, and is sensitive to individual differences in trait eating behaviours (Dalton & Finlayson, 2014) .

Data analyses

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

Results

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

Table 1.

Mean and SD characteristics (n = 168)

Variable	*M*	*SD*
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

BMI: Body Mass Index (kg/m^2); IW_HFSWBIS: Behavioural Inhibition System; BAS: Behavioural Activation System; EC-T: Effortful Control Total Scale; D: Disinhibition Scale; IW_HFSW: Implicit wanting high-fat sweet; EL_HFSW: Explicit liking high-fat sweet

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

Table 2.

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

Variables	*M*	*SD*	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
*$p < .05$, ** $p < .01$

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

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

Table 3

Hierarchical multiple regression analysis predicting implicit wanting for high-fat 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.
* $p < .05$, ** $p < .01$

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

Table 4

Hierarchical multiple regression analysis predicting explicit liking for high-fat sweet 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.
* $p < .05$, ** $p < .01$, *** $p < .001$

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

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

Table 5

Hierarchical multiple regression analysis of variables predicting Disinhibition (*N* = 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

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

Discussion

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

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

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

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

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

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

26.6 years and BMI of 26.7kg/m^2. Although not a specific focus of this study, neither the BAS nor the BIS were significantly correlated with Disinhibition, r = 0.13, (*ns)* and r = -0.022 (*ns*), respectively. Yeomans and Brace (2015) investigated whether acute exposure to food stimuli enhanced impulsive responding and risky decision-making in a sample of 96 healthy females (average age 21.4 years and BMI 22.6kg/m^2) classified with a tendency towards overeating (TFEQ-D), and whether these relationships were related to BIS/BAS scale scores. In this study, a trend for a small positive correlation between the BAS and Disinhibition was observed, r = 0.20, (p = 0.052), however, a correlation result between the BIS and Disinhibition was not reported.

It is possible that a direct association between the BAS and trait Disinhibition was difficult to establish in the current sample because BAS reactivity, as characterised by the BAS scale, may not provide a sensitive measure of trait, opportunistic overeating, i.e. Disinhibition (Bryant et al., 2008) in overweight and obese samples such as the present study and the study by Dietrich et al. (2014). This reasoning is supported by the research findings of O'Neil et al. (2012), who used principal component analysis (PCA) to investigate the relationship between fat mass, eating behaviour and psychological traits in a sample with a similar BMI (M = 30.5 kg/m^2, SD = 4.0) and age (M = 41.6, SD = 10.3) to the present study. Their first analysis explored the degree of association and commonality within the eating behavioural questionnaires. This PCA included three measures of eating behaviour and two measures of psychological traits, which included the TFEQ-D and BIS/BAS scales. From this analysis, two significant components emerged to describe the sample: A psychological component that corresponded to reward sensitivity and an eating behaviour component that corresponded to binge/overeating. Within the psychological component, the BAS reward responsiveness subscale was the most strongly correlated of all the BIS/BAS subscales. However, this component was found to be only weakly, negatively correlated to the eating behaviour component. Therefore, these results appear to support the suggestion that in the overweight and obese, reward sensitivity might not be a sensitive measure of tendency towards disinhibited eating.

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

Further evidence to support this line of reasoning is provided as follows: Lower average BMI, Disinhibition and BIS scores were found in the samples of Yeomans and Brace (2015, S1 Dataset) (BMI: 22.6 kg/m^2, BIS: 11.9, Disinhibition: 6.9) and Dietrich et al. (2014) (BMI: 26.7 kg/m^2, BIS: 17.0, Disinhibition: 6.1), when compared with that of O'Neil et al. (2012) (BMI: 30.5 kg/m^2, BIS: 18.6, Disinhibition: 8.7), and the present study (BMI: 33.33 kg/m^2, BIS: 21.39, Disinhibition: 9.2). When these results are considered from the lowest to the highest level of BMI, they suggest that BIS and Disinhibition scores increase alongside BMI. Therefore, a positive association between the BIS and trait Disinhibition could be difficult to establish in individuals of normal or close to normal levels of body weight.

For this same reason, a higher BMI could also have reduced the likelihood of finding a relationship between the BAS and Disinhibition. For example, it has been established that an inverse-U relationship between the BAS and BMI exists in adults, adolescents and children (Davis & Fox, 2008; Dietrich et al., 2014; Verbeken, Braet, Lammertyn, Goossens, & Moens, 2012). Within this relationship, the BAS is positively linked to BMI as it increases to approximately 30kg/m^2. However, as BMI increases beyond 30kg/m^2 the relationship becomes negative. This study's findings suggest that individuals with a higher mean BMI might be predisposed to eat in response to BIS sensitivity and not only to BAS sensitivity.

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

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

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

Sprangers & Schwartz, 1999). These phenomena have been described as particularly relevant for people living with long term conditions (Agborsaangaya, Lau, Lahtinen, Cooke, & Johnson, 2013) such as being overweight or obese. Moreover, as the variables were measured at the one time-point causal links between psychobiological temperaments, eating behaviour and food reward cannot be established. Furthermore, it is noted that the present study had higher mean BIS scores than those reported in O'Neil et al. (2012) who also excluded individuals who suffered from a psychiatric condition whereas this study did not. As the BIS/BAS scales capture an individual's susceptibility to experience anxiety (Carver & White, 1994), the higher BIS scores in this study may also reflect the inclusion of individuals with a diagnosis of anxiety or depression. Subsequently, this study may not generalise to populations where people with psychological comorbidities have been excluded. Finally, this study was conducted in overweight and obese adults with a mean age of 45.88 years (*SD* 12.16) therefore, these findings may not generalise to younger adults with a BMI less than 25 kg/m^2.

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

In conclusion, the results of this study suggest that, within a dual-process model of temperament, a sensitive BIS and lower levels of effortful control may increase risk of hedonically motivated disinhibited eating behaviour. The temperament model considered within this research is constitutional (Rothbart et al., 2013): An individual with a sensitive BIS may never have learnt to effectively manage their level of emotional reactivity. Therefore, it may be unrealistic to expect individuals who have learnt to consume highly palatable foods to regulate affect to successfully change their eating behaviour; unless they are simultaneously taught strategies, which either strengthen, conserve or replenish their capacity for effortful control.

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