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Exploring food reward and calorie intake in self-perceived food addicts

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Abstract

Previous research indicates that many people perceive themselves to be addicted to food. These 'self-perceived food addicts' may demonstrate aberrant eating patterns which put them at greater risk of overeating. However this is yet to be empirically investigated. The current study investigated whether self-perceived food addicts would exhibit higher food reward and calorie intake in a laboratory context relative to self-perceived non-addicts. A secondary aim was to investigate whether self-perceived food addicts would demonstrate increased food liking and/or increased hunger ratings. Finally, we explored whether self-perceived food addicts demonstrate patterns of aberrant eating, beyond that predicted by measures of trait dietary disinhibition and restraint. Female participants (self-perceived food addicts n=31, non-addicts n=29) completed measures of hunger, food reward (desire-to-eat, willingness-to-pay ratings, and an operant response task) and liking for high- and low-fat foods. Participants completed all measures when they were hungry, and again when they were satiated after consuming a fixed-lunch meal. Finally, participants were provided with *ad-libitum* access to high-and low-fat foods. Results indicated that self-perceived food addicts consumed more calories from high-fat food compared to non-addicts, despite the absence of any between-group differences in hunger or overall liking ratings. Self-perceived food addicts also displayed higher desire-to-eat ratings across foods compared to non-addicts, but groups did not differ on other measures of food reward. However, the differences in calorie intake and desire-to-eat between self-perceived food addicts and non-addicts were no longer significant after controlling for dietary disinhibition and restraint. These findings suggest that self-perceived food addicts experience food as more rewarding and have a tendency to overeat. However, this may be attributable to increased dietary disinhibition and decreased restraint rather than reflecting a unique pattern of aberrant eating behaviour.

Key words: food addiction; reward; liking; hunger; disinhibition; restraint

Introduction

The idea that certain foods have addictive properties similar to drugs of abuse is widely debated within the scientific community. While similarities have been identified between the neuro-behavioural effects of drugs and palatable food (e.g. Davis et al., 2011; Gearhardt et al., 2011), the extent to which excessive food intake is analogous to a substance abuse model remains a point of contention (Ziauddeen, Farooqi, & Fletcher, 2012; Hebebrand et al., 2014). Despite this, support for the concept of food addiction appears to be strong amongst members of the lay public (Lee et al., 2013; Ruddock, Dickson, Field, & Hardman, 2015). In a recent study, 86% of Australians and Americans believed that certain foods are 'addictive'", and 72% believed that food addiction causes some cases of obesity (Lee et al., 2013). Furthermore, between 28 and 52% of people from community samples believe that they are 'addicted' to food (Hardman et al., 2015; Meadows & Higgs, 2013; Ruddock et al., 2015), indicating that self-perceived food addiction is prevalent within the general population.

To date, we know very little about the characteristics of people who *perceive* themselves to be 'food addicts'. To address this, in a previous qualitative study, we identified several core behaviours which characterise self-perceived food addicts (Ruddock et al., 2015). These included a tendency to eat for reward, rather than physiological hunger, frequent food cravings, diminished self-control around food, a particular problem controlling consumption of foods high in fat, and a preoccupation with food and eating. Our study also suggested differences between self-perceived food addiction and the clinical definition of food addiction used by the Yale Food Addiction Scale (YFAS) (Gearhardt, Corbin, & Brownell, 2009), which is based upon the Diagnostic Statistical Manual IV (DSM-IV) criteria for substance dependence. Specifically, contrary to the YFAS definition, self-perceived food addiction was not thought to be characterised by 'significant distress' or an 'impairment to daily functioning'. Consistent with this, other studies indicate that the majority of self-perceived food addicts do not meet the YFAS diagnostic criteria for food addiction (Hardman et al., 2015; Meadows & Higgs, 2013).

Despite not necessarily fulfilling an established criterion for food addiction (i.e. the YFAS), there is evidence to suggest that self-perceived food addicts have problematic patterns of eating and may be at risk of overeating. Specifically, a previous study found that self-perceived food addicts scored significantly higher on measures of pathological eating compared to self-perceived non-addicts (Meadows & Higgs, 2013). Furthermore, a number of laboratory studies have shown increased desire for and greater intake of chocolate in self-diagnosed chocolate addicts compared to non-addicts (Hetherington & Macdiarmid, 1995; Macdiarmid & Hetherington, 1995; Tuomisto et al., 1999).

Building on these preliminary findings, the aim of the current study was to examine the behavioural characteristics of individuals who perceive themselves to be 'food addicts'. Specifically, (and following on from Hetherington & Macdiarmid, 1995; Macdiarmid & Hetherington, 1995; Tuomisto et al., 1999) we sought to determine whether self-perceived food addicts would exhibit higher food reward and calorie intake in a laboratory context relative to non-addicts. We employed the following three measures as proxy indicators of food reward – 1) desire-to-eat ratings for a portion of food, 2) by asking participants to indicate how much money they would be willing to pay for a portion of food, and 3) an operant response task in which participants repeatedly tapped a computer key, within a 1-minute time period, in exchange for larger portions of food. These measures have been validated by Rogers and Hardman (2015) and used in previous studies on food reward (Brunstrom & Rogers 2009; Hardman, Herbert, Brunstrom, Munafò, & Rogers, 2012). Previous studies indicate that individual differences in food reward are most apparent when participants are satiated relative to in a hungry state (Castellanos et al., 2009; Dalton, Blundell, & Finlayson, 2013; Nasser et al., 2008). We therefore assessed participants in both hungry and satiated states and we expected to see a greater difference between self-perceived addicts and non-addicts in the latter state. We also expected self-perceived food addicts to find high-fat foods more rewarding relative to low-fat foods and to consume more of these foods *ad-libitum,* compared to non-addicts. This is consistent with our previous findings in which self-perceived food addicts reported a tendency to overeat high-fat foods (Ruddock et al., 2015). Similarly, another study found that high-fat foods, such as chocolate and crisps, were regarded as more 'addictive' than low-fat foods, such as fruit and plain crackers (Schulte, Avena, & Gearhardt, 2015).

A secondary aim of our study was to investigate whether self-perceived food addicts would demonstrate increased food liking and/or increased hunger ratings. Hunger and food liking are thought to represent measurable components of food reward (Berridge, Ho, Richard, & Difeliceantonio, 2010; Rogers & Hardman, 2015), and so we may find that either, or both, of these are increased in those with heightened food reward. However, previous research has yielded inconsistent findings regarding this. In one study, self-diagnosed 'chocolate addicts' had increased levels of food reward (i.e. desire to eat) but did not differ from controls on measures of hunger and liking for chocolate, prior to chocolate consumption (Hetherington & Macdiarmid, 1995). In contrast, increased chocolate liking has been observed in self-reported 'chocolate cravers' (Gibson & Desmond, 1999), and Finlayson et al. (2011) demonstrated increased hunger perceptions in those with a propensity to overeat.

A further secondary aim was to establish the extent to which self-perceived food addicts demonstrate patterns of aberrant eating behaviour that are distinct from those captured by existing measures of dietary disinhibition (i.e. loss of control over intake) and restraint (i.e. attempts to restrict intake). This is important as food addiction is considered to be a distinct clinical condition, which nonetheless overlaps with other forms of pathological eating such as binge eating (Davis, 2016). It is therefore necessary to establish the extent to which the concept of food addiction *uniquely* predicts patterns of overeating (Long, Blundell, & Finlayson, 2015). To address this, we explored the extent to which self-perceived food addiction predicts increases in food reward and calorie intake over and above that accounted for by high dietary disinhibition and low restraint. Dietary disinhibition was measured using the Binge Eating Scale (Gormally, Black, Daston, & Rardin, 1982) and the disinhibition subscale of the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985), both of which are thought to reflect differing degrees of 'uncontrolled' or disinhibited eating (Vainik et al., 2015). Dietary restraint was assessed using the restraint subscale of the TFEQ which assesses successful restraint (Heatherton et al., 1988) and, accordingly, in our study we considered low dietary restraint as a risk factor for overeating (Rollins, Loken, & Birch, 2011). These measures demonstrate good predictive validity for *ad-libitum* food intake, eating psychopathology, and the tendency to engage in uncontrolled eating (Duarte, Pinto-Gouveia, & Ferreira, 2015; Ouwens, van Strien, & van der Staak, 2003; Rollins, Loken, & Birch, 2011).

To summarize, the aims of the current study were as follows; (1) To investigate whether self-perceived food addicts would demonstrate increased food reward (most notably when satiated), and would subsequently consume more calories when given *ad-libitum* access to high- and low- fat foods compared to non-addicts. In particular, these differences were expected to be most pronounced towards the high-fat foods. (2) To test the hypothesis that increased food reward in self-perceived food addicts would be accounted for by increased liking for the test foods, and/or increased hunger, (3) To explore the extent to which self-perceived food addiction predicts increased food reward and calorie intake over and above existing measures of binge eating, dietary disinhibition and restraint.

Method

Participants

Participants (*N*=64) were recruited from the University of Liverpool via poster and online advertisements. As this was a preliminary study into self-perceived food addiction, we restricted the sample to females in order to minimize between-subject differences as a result of gender. Participants were purposefully recruited such that approximately half were self-perceived food addicts. To achieve this, after approximately 30 self-perceived non-addicts had been recruited, we restricted recruitment to self-perceived food addicts *only*. This was specified in the inclusion criteria displayed on study advertisement posters, and on the participant information sheet. Self-perceived food addiction was assessed using a self-report measure (see Measures section for details). Participants were excluded from the study if they had any food allergies or intolerances, had ever been diagnosed with an eating disorder, were on any medication which may affect appetite, or if they smoked tobacco. Ethical approval was granted by the University Research Ethics Committee. In exchange for their time, participants received course credits or a £5 shopping voucher.

Measures

Assessment of self-perceived ‘food-addiction’. As in previous research (Hardman et al., 2015; Ruddock et al., 2015), to assess self-perceived food addiction, participants were asked ‘Do you agree with the following statement: “I believe myself to be a food addict”?’. Participants were required to tick either ‘yes’ or ‘no’. For the purposes of our analyses, participants who ticked ‘yes’ were classified as ‘self-perceived food addicts’, and participants who ticked ‘no’ were classified as non-addicts.

Ratings task. For the ratings task, participants were presented with four small plates each with a sample of chocolate (6 x Galaxy Minstrels, 16.4g, 83 kcals, 3.7g fat), crisps (6 x HP Hula Hoops, 4.9g, 25 kcals, 1.3g fat), grapes (6 x seedless green grapes, 38g, 27 kcals, 0.0g fat), and six pieces of Tesco lightly salted rice cake (5.6g, 22 kcals, 0.2g fat). These foods were specifically chosen to provide two high fat foods which are commonly reported as ‘addictive’ or ‘problematic’ (Schulte et al., 2015) (crisps and chocolate) and two low fat foods (grapes and rice cakes), which are not regarded as particularly addictive (Schulte et al., 2015). For each food, participants were instructed to place one piece in their mouth and complete the rating scales in the following order: ‘Liking’, ’Desire-to-eat’, and ‘Willingness to pay’ (following the procedure of Rogers & Hardman, 2015). The order in which each food was rated was counterbalanced across participants.

Liking. Liking ratings for each of the test foods were obtained using a 100mm VAS with end anchor points ‘Not at all’ and ‘Extremely’ to the left and right of the scale, respectively. The following instructions were given to encourage participants to focus on the taste of the food, as opposed to the pleasantness of actually ingesting it: *How much do you like the taste of this food? That is, how pleasant does it taste in your mouth RIGHT NOW? When making this judgement, IGNORE how much or little of the food you want to eat, and what it would be like to chew and swallow it – JUST FOCUS PURELY ON ITS TASTE IN YOUR MOUTH.*

Desire-to-eat (Food reward). Having completed the liking measure**,** a measure of ‘Desire-to-eat’ (DtE) was obtained for the remaining amount of each of the test foods using a 100mm VAS with end anchor points ‘Not at all’ and ‘Extremely’ to the left and right of the scale, respectively. Participants were instructed to indicate how much they desired to eat each of the foods ‘right now’. Using desire-to-eat ratings in this way has been shown to provide a valid measure of food reward (Rogers & Hardman, 2015).

Willingness to pay (Food reward). Using a 100mm VAS, participants were asked to indicate how much money they would be 'willing to pay' (WtP) for the remaining amount of each of the test foods. The VAS ranged from 1p on the left to £2 on the right, and £1 marked the mid-point of the scale. This task has been used in previous research to reflect the rewarding value of food (e.g. Hardman et al., 2012).

Operant task (Food reward). An operant response task was included to assess participants' motivation to obtain chocolate and grapes. The task was programmed using E-prime 2.0 (Psychology Software Tools, Inc. Sharpsburg, PA, USA). For chocolate and grapes only, participants were required to tap the spacebar on a computer keypad for 60 seconds. They were informed that the more they tapped the space bar during this time, the more of each food they would receive at the end of the session. Previous research has demonstrated the validity of this task as a measure of food reward (Rogers & Hardman, 2015). The order in which participants tapped for chocolate and grapes was counterbalanced across participants. This task was performed for two out of the four test foods (i.e. a high-fat sweet food and low-fat sweet food) in order to minimize the potential confounding effects of participant fatigue.

Appetite. Hunger and fullness ratings were obtained using 100mm visual analogue scales (VAS). Each scale was marked by anchor points 'Not at all' on the left and 'Extremely' on the right.

Familiarity ratings. Participants were asked to indicate how often they consumed each of the four test foods. The following response options were given: 'Never', 'Monthly or less', '2-4 times a month', '2-3 times a week', '4 or more times a week', and 'Every day'. Participants indicated how often they ate each food by ticking the appropriate box.

Questionnaires.

Three Factor Eating Questionnaire (TFEQ). Participants completed the 'Restraint' (TFEQ-R) and 'Disinhibition' (TFEQ-D) sub-scales of the TFEQ (Stunkard & Messick, 1985). Dietary restraint refers to attempts to restrict food intake, while disinhibition refers to the general tendency to overeat. The TFEQ-R sub-scale comprises 21 items such as "I have a pretty good idea of the number of calories in common foods". The TFEQ-D sub-scale consists of 16 items such as "I usually eat too much at social occasions like parties and picnics".

Binge Eating Scale (BES). The BES (Gormally, Black, Daston, & Rardin, 1982) consists of 16 items which assess the severity of binge eating symptoms. Each item consists of three or four statements about eating behaviours or emotions associated with binge-eating. Instructions are given to mark the statement within each item which the participant most identifies with. Higher scores on the BES indicate more severe binge eating symptoms.

Yale Food Addiction Scale (YFAS). The YFAS (Gearhardt et al., 2009) consists of 25 items designed to measure an addiction to foods high in fat and/or sugar. The scale is based on the DSM-IV criteria for substance dependence. For the first 16 items, a Likert scale is used in which the respondent indicates how often, in the past 12 months, they have engaged in a particular behaviour (for example "I eat to the point where I feel physically ill"). For the next 9 items, respondents indicate whether or not they agree with each statement by marking either 'Yes' or 'No' (for example, "I want to cut down or stop eating certain kinds of foods"). Respondents are asked to base their response on their experiences in past 12 months. In the final item, respondents are asked to indicate all foods that they have problems with. A diagnosis of food addiction is given when the individual demonstrates significant clinical impairment due to their eating behaviours, and fulfills at least three of the following symptoms: unsuccessful attempts to quit, giving up activities to eat, eating large portions, continuing to overeat despite negative consequences, tolerance to food, withdrawal from not eating, and spending a lot of time eating. The YFAS also provides a continuous measure of the number of food addiction symptoms exhibited by an individual (i.e. symptom count) which range from 0 to 7. The YFAS was included to provide descriptive information about the characteristics of our sample, and was not central to the aims and objectives of the study. In particular, we included this measure to confirm previous findings in which few self-perceived food addicts met the YFAS-criteria for food addiction (Hardman et al., 2015; Meadows & Higgs, 2013).

Lunch meal

To induce satiety, participants were provided with cheese sandwiches. Sandwiches were made using 3 pieces of medium sliced white bread (Tesco 'Stay Fresh', 121.2g, 303kcals, 2.4g fat), 1.5 pieces of pre-sliced cheddar cheese (Tesco medium cheddar, 37.5g, 152 kcals, 13.0g fat), and 15g butter (Tesco Butterpak, 95 kcals, 10.5g fat). These were then sliced into 6 small sandwiches. This meal size was based on the amount of cheese sandwiches consumed *ad-libitum* in previous research (Rogers & Hardman, 2015). Participants were given 10 minutes in which they were instructed to consume the entire meal. All but four participants complied with this instruction. These four participants were within the healthy weight range (i.e. 18.5 kg/m^2 <BMI<24.9 kg/m^2), and one identified as a food addict.

Procedure

All participants attended one testing session which took place at the Ingestive Behaviour Laboratory at the University of Liverpool. Figure 1 illustrates the study procedure. Prior to testing, participants were asked to eat their usual breakfast but then to refrain from consuming any food or calorie-containing drinks for 3 hours before the start of their session. All participants indicated that they had adhered to this instruction. Participants were tested individually, and all sessions took place between 12pm and 2pm. Upon arrival, participants were provided with information about the study and signed a consent form. Participants then completed a medical history questionnaire to ensure that they did not have any food allergies.

Participants indicated their current level of hunger and fullness (T1). This was followed by the ratings task in which participants indicated their Liking, Desire-to-eat (DtE) and Willingness to Pay (WtP) for each of the four foods. Participants then completed the ‘tapping task’ for chocolate and grapes, and levels of hunger and fullness were reassessed (T2). Participants then consumed the lunch meal, after which they were given a 5-minute break. During the break, participants could either sit quietly or engage in some light reading. Hunger and fullness levels were reassessed at this stage (T3), followed by the post-lunch ratings task and tapping task. To provide a valid comparison of food reward between hungry and satiated states, it was important that participants believed that the outcome of the tapping task (i.e. the amount of food they would receive) would not be influenced by their previous performance on the task. Therefore, participants were told that their results from the earlier tapping task had failed to save on the computer and therefore would not affect how much food they would receive at the end of the session (as used in Rogers & Hardman, 2015). Levels of hunger and fullness were reassessed (T4). Participants were then given *ad-libitum* access to 160g of chocolate (Galaxy Minstrels 805 kcals, 35.7g fat) and 200g of grapes (140 kcals, 0.2g fat) under the pretense that that they had ‘earned’ these foods during the tapping task. Participants were told that they could eat as much of the food as they wished and to let the experimenter know when they had had enough. Following this, participants were again required to indicate their levels of hunger and fullness (T5).

The remaining measures were administered in the following order: Familiarity ratings, TFEQ, BES, YFAS, self-perceived ‘food-addiction’. Participants’ height and weight were also assessed to provide a measure of body mass index (BMI).

Finally, to ensure the absence of demand characteristics, participants were asked to indicate what they thought the aims of the study were. No participants guessed correctly. Participants were then fully debriefed.

Data analysis

Liking, desire-to-eat (DtE), and willingness to pay (WtP) ratings were assessed using mixed design ANOVAs with a between-subject factors of Group (2: self-perceived food addicts/non-addicts) and within-subject factors of Time (2: before and after the lunch meal) and Food type (4: chocolate, crisps, rice cakes, grapes). Tapping frequency during the operant task was assessed using a 2(group) x 2(time) x 2(food type: chocolate/grapes) mixed-design ANOVA. For each analysis, food type and time were entered as within-subjects variables, and group was included as a between-subjects variable. Calorie intake was analysed using a 2 (food type: chocolate/grapes) x 2(group) mixed-design ANOVA. Group differences in hunger ratings were explored using a 2 (group) x 5 (time) mixed-design ANOVA with time as a within-subjects variable, and group as a between-subjects variable.

Hierarchical regression analyses were conducted to examine the extent to which self-perceived food addiction could account for group differences in food reward and calorie intake, over and above that accounted for by dietary disinhibition and restraint. Scores from the BES and TFEQ disinhibition subscale were highly correlated, $r=.725$, $p<.001$. Therefore, to avoid problems arising from multi-collinearity of predictor variables, a single ‘disinhibited eating index’ was calculated using the mean of the combined z-scores from these two measures (Thush et al., 2008). TFEQ-restraint subscale scores were also transformed to z-scores prior to analysis. Disinhibited eating index and TFEQ-restraint (z-scores) were then entered into the first step of the regression model, and group (i.e. self-perceived food addicts vs. non-addicts) was entered into the second step. Measures of food reward and calorie intake (where prior analyses revealed between-group differences) were entered as dependent variables.

Results

Participant characteristics

Participants who did not consume the entire set lunch were excluded from the analysis (*N*=4) leaving a total of 60 participants (self-perceived food addicts *n*=31; non-addicts *n*=29)[1]. Post-hoc power analyses, using GPower 3.1, indicated that the current sample yielded 76% power to find significant interactions and differences between groups on measures of food reward and calorie intake, of medium effect sizes (f=.35, α =.05). For the regression analyses, the sample size yielded 83% power to detect a medium effect size (f^2=.15) (α =.05). Participants were aged between 18 and 54 years (*M*=23.92, *S.D.*=9.38 y) and had a mean BMI of 23.72 kg/m^2 (*S.D.*=4.57). Nine participants (15%) were classified as overweight (BMI>25 kg/m^2) and 7 (12%) were classified as obese (BMI > 30kg/m^2). Of the 60 participants, 31 identified as food addicts and 29 identified as non-food addicts. Self-perceived food addicts endorsed significantly more YFAS symptoms (p<.001), but were *not* more likely to fulfill the YFAS diagnosis for food addiction, relative to non-food addicts (see Table 1). Self-perceived food addicts also scored significantly higher on the BES and TFEQ-D sub-scale, compared to non-addicts. Importantly, groups did not differ on BMI or age (see Table 1). BMI did not correlate with any dependent variable and therefore was not included as a covariate in subsequent analyses.

[1] Analyses were re-run with these four participants included. Results remained the same, however the main effect of group on DtE only approached significance, $F(1,62)=3.54$, $p=.065$.

Measures of food reward

The predicted 3-way time x food type x group interaction was not significant for any of the three reward measures (i.e. DtE, WtP, and tapping frequency –Table 2) (ps>.206). However, our primary hypothesis was partially supported by a main effect of group on overall DtE ratings, $F(1,58)=6.08$, $p=.017$, $\eta_p^2 =.095$, such that self-perceived food addicts demonstrated increased overall DtE ratings compared to non-addicts. There was no main effect of group on WtP ratings, $F(1,58)=.35$, $p=.557$, $\eta_p^2 =.006$, or tapping frequency $F(1,58)=1.13$, $p=.293$, $\eta_p^2 =.019$. No 2-way interactions were observed between group x time (ps >.081), or group x food type (ps>.237) for any measure of food reward. Main effects of time revealed that all three measures of food reward decreased significantly following consumption of the lunch meal (Table 2) (DtE: $F(1,58)=124.75$, $p<.001$, $\eta_p^2 =.685$; WtP: $F(1,58)=47.95$, $p<.001$, $\eta_p^2 =.453$; Tapping frequency: $F(1,58)=40.35$, $p<.001$, $\eta_p^2 =.410$).

Calorie intake

Consistent with our primary hypothesis, a main effect of group, $F(1,58)=8.65$, $p=.005$, $\eta_p^2 =.130$, showed that food addicts consumed significantly more calories overall (Figure 2). There was also a main effect of food, $F(1,58)=65.40$, $p<.001$, $\eta_p^2=.530$, such that participants consumed significantly more calories from chocolate ($M=235.70$, $S.D.=187.07$) than from grapes ($M=56.50$, $S.D.=37.60$). These main effects were subsumed under the hypothesised 2-way food type x group interaction, $F(1,58)=6.64$, $p=.013$, $\eta_p^2 =.103$. Follow-up univariate ANOVAs showed that food addicts consumed more chocolate, $F(1,58)=7.98$, $p=.006$, $\eta_p^2=.121$, but not more grapes, $F(1,58)=2.83$, $p=.098$, $\eta^2=.046$, than non-addicts (Figure 2). The between-group effect on chocolate consumption remained significant when using a Bonferroni adjustment for multiple comparisons.

Food liking and hunger

There was no group x time interaction, $F(1,58)=.07$, $p=.799$, $\eta_p^2=.001$, and no main effect of group on hunger ratings, $F(1,58)=.30$, $p=.589$, $\eta_p^2=.005$. Furthermore, there was no main effect of group on overall liking ratings for the test foods, $F(1,58)=.31$, $p=.583$, $\eta_p^2=.005$. However, a group x time interaction for liking ratings was observed, $F(1,58)=5.43$, $p=.023$, $\eta_p^2=.086$. To explore this further, we calculated the decline in liking ratings for each participant (collapsed across all test foods) by subtracting average liking ratings when satiated, from average liking when hungry. This 'liking decline' value was then entered into an independent t-test which revealed that self-perceived food addicts demonstrated less of a decline in 'liking' ratings for the test foods following the lunch meal compared to non-addicts, $t(58)=2.33$, $p=.023$ (Figure 3, panel A).

A main effect of time was observed on hunger ratings, $F(1,58)=412.26$, $p<.001$, $\eta_p^2=.877$. Specifically, hunger ratings were significantly greater at both T1 and T2 (i.e. prior to the lunch meal) compared to at T3 and T4 (i.e. following the lunch meal). Hunger ratings at T5 (i.e. following *ad-libitum* food intake) were significantly lower than at all other time-points (Figure 3, panel B).

Regression analyses

The results of the regression analyses revealed that group (i.e. self-perceived food addicts vs. non-addicts) failed to account for variance in total calories consumed (Table 3), or overall DtE ratings (Table 4), over and above that predicted by the disinhibited eating index and TFEQ-restraint (z-scores). Disinhibition was a significant positive predictor and restraint a significant negative predictor of calorie intake; however, these relationships became nonsignificant when self-perceived food addiction was added to the model. For desire-to-eat ratings, disinhibition was the only significant predictor at both stages in the model. Tolerance (.67) and VIF (1.50) values indicated no problems with multi-collinearity between predictor variables (i.e. disinhibition, TFEQ-restraint, and group) in either regression model (Menard, 1995; Myers, 1990).

Discussion

According to recent studies, between 28 and 52 per cent of community samples perceive themselves to be addicted to food (Hardman et al., 2015; Meadows & Higgs, 2013; Ruddock et al., 2015). While the majority of self-perceived food addicts do not fulfil the diagnostic criteria for food addiction established by the YFAS (Gearhardt et al., 2009), previous research suggests that these individuals may demonstrate increased patterns of problematic eating (Meadows & Higgs, 2015; Ruddock et al., 2015). As such, self-perceived food addicts may represent a group of individuals who are at particular risk of overeating.

To address this possibility, the current study investigated whether self-perceived food addicts would demonstrate increased food reward, particularly when satiated, and would consume more calories when provided with *ad-libitum* access to high- and low- fat foods, compared to those who did not identify as food addicts. In particular, we expected to observe individual differences in reward and intake for foods that were high in fat. Food reward for high- and low-fat foods was assessed using desire-to-eat ratings, willingness to pay ratings, and an operant response task, consistent with methods used in previous research (Brunstrom & Rogers, 2009; Hardman et al., 2012; Rogers & Hardman, 2015). All measures of reward were taken when participants were hungry, and again when they were satiated after consuming a fixed sandwich-lunch meal.

Consistent with our hypothesis, self-perceived food addicts consumed more calories *ad libitum* from the high-fat food (i.e. chocolate), and more calories overall, compared to non-addicts. As predicted, groups did not differ in their intake of the low-fat food (i.e. grapes). Furthermore, self-perceived food addicts demonstrated increased *overall* desire-to-eat ratings for the test foods compared to non-addicts. However, contrary to our hypothesis that individual differences in food reward would be most pronounced in the satiated condition and towards the high-fat food, this effect was apparent in *both* the hungry and satiated states and across high-fat and low-fat food types. Also contrary to our hypothesis, the groups did not differ on the other measures of food reward (i.e. tapping frequency and willingness-to-pay measures).

Together, the current findings are partially consistent with previous research in which self-perceived food addicts and ‘chocolate addicts’ reported increased desire for food and showed a propensity to overeat (Hetherington & Macdiarmid, 1995, Macdiarmid & Hetherington, 1995; Ruddock et al., 2015; Tuomisto et al., 1999). The current study extends these findings by demonstrating increased food reward in self-perceived food addicts, for a *range* of foods, when hungry and satiated. These differences in eating behaviour were observed despite the fact that very few (four participants out of 31; 13%) self-perceived food addicts fulfilled the YFAS diagnostic criteria. This is important as, consistent with previous findings (Meadows & Higgs, 2013), it suggests that self-perceived food addicts represent a population of individuals who have an increased tendency to overeat, and this may go undetected by an existing measure of addictive eating. Importantly, while no weight differences were observed between self-perceived food addicts and non-addicts in our study, this may be attributable to the young age of the sample. Indeed, in our previous research, which consisted of a slightly older demographic (i.e. mean age = 29 years), we found increased incidences of self-perceived food addiction amongst those with higher BMI (Ruddock et al., 2015).

Hunger and liking for the taste of a food are thought to represent measurable components of food reward (Berridge et al., 2010; Rogers & Hardman, 2015). On this basis, a further aim of the current study was to explore whether increased food reward in self-perceived food addicts was attributable to increased food liking and/or increased hunger ratings. There was no overall difference between the groups on liking for the test foods. This is consistent with previous research which found increased food reward in ‘chocolate addicts’, despite no differences in food *liking* (Hetherington & Macdiarmid, 1995). Similarly, we did not observe any between-group differences in hunger ratings at any point in the study, despite the fact that the self-perceived food addicts consumed significantly more chocolate between T4 and T5 than did non-addicts. This is important because it indicates that increased food reward and chocolate intake in the self-perceived food addicts relative to the non-addicts cannot be due to differences in hunger state. Notably, Hetherington and Macdiarmid (1995) also found that chocolate overeaters had higher desire to eat but were not hungrier or less full than controls at baseline (i.e. prior to consuming a chocolate snack).

Nonetheless, while *overall* liking ratings for the test foods did not differ between groups, self-perceived food addicts demonstrated an attenuated decline in liking ratings following consumption of the fixed sandwich lunch meal relative to non-addicts. Future research should explore the possibility that self-perceived food addicts experience less of a reduction in the hedonic value of a food’s taste following satiety per se or repeated consumption of a similar taste (i.e. sensory specific satiety). Indeed, Hetherington and Macdiarmid (1995) reported smaller changes in chocolate pleasantness ratings following chocolate consumption in chocolate overeaters, compared with control participants.

Similarly, obese women demonstrated an attenuated decrease in the hedonic value of a sweet tasting solution over repeated trials compared to lean women (Pepino & Mennella, 2012).

A further secondary aim of the current study was to establish the extent to which self-perceived food addiction uniquely predicts overeating and increased food reward. This follows recent suggestions that food addiction may be a novel term that is used to describe already established patterns of overeating (Long et al., 2015; Vainik et al., 2015). In the current study, self-perceived food addiction failed to predict a significant proportion of the variance in calorie intake and food reward (i.e. overall desire-to-eat ratings) beyond that accounted for by dietary disinhibition and restraint. This suggests that members of the lay public may use the term 'food addiction' as a means of conceptualizing patterns of overeating that are already captured by established trait measures of dietary behaviour. Notably, in our study, food intake was predicted by both increased dietary disinhibition *and* reduced dietary restraint and this is consistent with dual system models of eating behaviour (Price, Higgs, & Lee, 2015).

The current study yields a number of limitations that should be addressed in future research. Firstly, while we specifically recruited non-smokers, we did not control for the use of other recreational drugs or alcohol. Given the association between aberrant eating behaviours and alcohol and drug use (e.g. Clark & Saules, 2013; Grucza et al., 2010; Lilenfeld et al., 2008), it is possible that those who identify as food addicts may have been more likely to use drugs and be heavy drinkers which may have affected our findings. Secondly, it is important to consider the choice of test foods used in the current study. Two high fat foods (chocolate and crisps) and two low fat foods (rice cakes and grapes) were selected to test the hypothesis that individual differences in food reward and calorie intake would be specific to high-fat foods which people typically report as 'addictive' (Schulte et al., 2015). However, with regards to food reward, no such group by food type interaction was observed. One possibility is that food reward may be particularly pronounced when self-perceived food addicts are presented with their particular 'problem' food. Thus future research into food reward may benefit from utilizing a more individualised approach in selecting test foods. Finally, it is important to consider the possibility that differences in food reward, pre- and post- meal consumption, may have been due to order-effects. This may be particularly the case for performance on the tapping task in which factors other than satiety (e.g. boredom) may have reduced performance on this task. However, as we were primarily interested in differences *between* groups (i.e. self-perceived food addicts versus non-addicts), this issue is unlikely to have affected our overall findings. Nonetheless, another important issue that should be addressed in future research concerns the order in which eating-related questionnaires are completed. In particular, it is possible that in the current study, completing the YFAS prior to the assessment of self-perceived food addiction may have influenced participants' responses on the latter.

Despite these limitations, the current study provides novel insight into patterns of eating which characterise a self-perceived addiction to food, and highlights a number of avenues for future research. In particular, it would be informative to compare YFAS-diagnosed food addicts with self-perceived food addicts on the measures of food reward and calorie intake. This was beyond the scope of the current study due to the very small number of YFAS-diagnosed food addicts (as would be expected based on previous research on self-perceived food addicts; Hardman et al., 2015; Meadows & Higgs, 2013). It will also be important to replicate the current findings in male participants and in larger and more diverse samples. Finally, it would be interesting for future research to more specifically explore how food reward and calorie intake in self-perceived food addicts may be differentially affected by various macronutrient food profiles (e.g. high-fat, high carbohydrate vs. high-fat low carbohydrate).

To conclude, the current study provides evidence for increased calorie intake in self-perceived food addicts, despite no differences in hunger or overall liking. Furthermore, compared to non-addicts, self-perceived food addicts displayed higher desire-to-eat ratings across foods, but did not differ on other measures of food reward (i.e. WtP and tapping frequency). However, differences in calorie intake and food reward between self-perceived food addicts and non-addicts were no longer significant after controlling for measures of dietary disinhibition and restraint. These findings suggest that self-perceived food addicts experience food as more rewarding and are at particular risk of overeating. However, this may be attributable to increased dietary disinhibition and decreased restraint rather than reflecting a unique pattern of aberrant eating behaviour.

References

Berridge, K. C., Ho, C. Y., Richard, J. M., & Difeliceantonio, A. G. (2010). The tempted brain eats: Pleasure and desire circuits in obesity and eating disorders. *Brain Research, 1350*, 43-64.

Brunstrom, J. M., & Rogers, P. J. (2009). How many calories are on our plate? Expected fullness, not liking, determines meal-size selection. *Obesity, 17*(10),1884–1890.

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., & Cowan, R. L. (2009). Obese adults have visual attention bias for food cue images: Evidence for altered reward system function. *International Journal of Obesity, 33*(9), 1063-1073.

Clark, S. M., & Saules, K. K. (2013). Validation of the Yale Food Addiction Scale among a weight-loss surgery population. *Eating Behaviors*, *14*(2), 216–219.

Dalton, M., Blundell, J., & Finlayson, G. (2013). Effect of BMI and binge eating on food reward and energy intake: further evidence for a binge eating subtype of obesity. *Obesity Facts, 6*(4), 348–359.

Davis, C., Curtis, C., Levitan, R. D., Carter, J. C., Kaplan, A. S., & Kennedy, J. L. (2011). Evidence that " food addiction " is a valid phenotype of obesity. *Appetite*, *57*(3), 711–717.

Davis, C. (2016). A commentary on the associations among 'food addiction', binge eating disorder, and obesity: Overlapping conditions with idiosyncratic clinical features. *Appetite*. http://dx.doi.org/10.1016/j.appet.2016.11.001

Duarte, C., Pinto-Gouveia, J., & Ferreira, C. (2015). Expanding binge eating assessment: Validity and screening value of the Binge Eating Scale in women from the general population. *Eating Behaviors, 18,* 41-47.

Finlayson, G., Arlotti, A., Dalton, M., King, N., & Blundell, J. E. (2011). Implicit wanting and explicit liking are markers for trait binge eating. A susceptible phenotype for overeating. *Appetite*, *57*(3), 722–728.

Gearhardt, A. N., Corbin, W. R., & Brownell, K. D. (2009). Preliminary validation of the Yale Food Addiction Scale. *Appetite*, *52*(2), 430–436.

Gearhardt, A. N., Yokum, S., Orr, P. T., Stice, E., Corbin, W. R., & Brownell, K. D. (2011). Neural Correlates of Food Addiction. *Archives of General Psychiatry*, *68*(8), 808–816.

Gibson, E. L., & Desmond, E. (1999). Chocolate Craving and Hunger State : Implications for the Acquisition and Expression of Appetite and Food Choice. *Appetite*, *32*(2), 219–240.

Gormally, J., Black, S., Daston, S., & Rardin, D. (1982). The assessment of binge eating severity among obese persons. *Addictive Behaviors*, *7*(1), 47–55.

Grucza, R. A, Krueger, R. F., Racette, S. B., Norberg, K. E., Hipp, P. R., & Bierut, L. J. (2010). The emerging link between alcoholism risk and obesity in the United States. *Archives of General Psychiatry*, *67*(12), 1301–1308.

Hardman, C. A, Herbert, V. M. B., Brunstrom, J. M., Munafò, M. R., & Rogers, P. J. (2012). Dopamine and food reward: effects of acute tyrosine/phenylalanine depletion on appetite. *Physiology & Behavior*, *105*(5), 1202–1207.

Hardman, C. A., Rogers, P. J., Dallas, R., Scott, J., Ruddock, H., & Robinson, E. (2015). "Food addiction is real": the effects of exposure to this message on self-diagnosed food addiction and eating behaviour. *Appetite, 91,* 179-184.

Heatherton, T. F., Herman, C. P., Polivy, J., King, J. A., & McGree, S. T. (1988). The (mis)measurement of restraint: An analysis of conceptual and psychometric issues. *Journal of Abnormal Psychology, 97,* 19-28.

Hebebrand, J., Albayrak, Ö., Adan, R., Antel, J., Dieguez, C., de Jong, J., … Dickson, S. L. (2014). "Eating addiction", rather than "food addiction", better captures addictive-like eating behavior. *Neuroscience & Biobehavioral Reviews, 47*, 295–306.

Hetherington, M.M. & Macdiarmid, J.I. (1995). Pleasure and excess: Liking for and overconsumption of chocolate. *Physiology and Behavior, 57*(1), 27-35.

Lee, N. M., Lucke, J., Hall, W. D., Meurk, C., Boyle, F. M., & Carter, A. (2013). Public views on food addiction and obesity: implications for policy and treatment. *PloS One, 8*(9), e74836.

Lilenfeld, L. R. R., Ringham, R., Kalarchian, M. A., & Marcus, M. D. (2008). A family history study of binge-eating disorder. *Comprehensive Psychiatry, 49,* 247–254.

Long, C. G., Blundell, J. E., & Finlayson, G. (2015). A Systematic Review of the Application And Correlates of YFAS-Diagnosed " Food Addiction " in Humans: Are Eating-Related " Addictions " a Cause for Concern or Empty Concepts? *Obesity Facts, 8*, 386–401.

Macdiarmid, J. L. & Hetherington, M. M. (1995). Mood modulation by food: An exploration of affect and cravings in "chocolate addicts". *British Journal of Clinical Psychology, 34*, 129–138.

Meadows, A., & Higgs, S. (2013). I think, therefore I am? Characteristics of a non-clinical population of self-perceived food addicts. *Appetite, 71*, 482.

Menard, S. (1995). *Applied Logistic Regression Analysis: Sage University Series on Quantitative Applications in the Social Sciences*. Thousand Oaks, CA: Sage.

Myers, R.H. (1990). *Classical and modern regression with applications*. Boston: PWS-Kent

Nasser, J. A, Evans, S. M., Geliebter, A., Pi-Sunyer, F. X., & Foltin, R. W. (2008). Use of an operant task to estimate food reinforcement in adult humans with and without BED. *Obesity, 16*(8), 1816–1820.

Ouwens, M.A., van Strien, T., & van der Staak, C.P.F. (2003). Tendency towards overeating and restraint as predictors of food consumption. *Appetite, 40*(1), 291-298.

Pepino, M. Y., & Mennella, J. A. (2012). Habituation to the pleasure elicited by sweetness in lean and obese women. *Appetite, 58*(3), 800–805.

Price, M., Higgs, S., & Lee, M. (2015). Self-reported eating traits: Underlying components of food responsivity and dietary restriction are positively related to BMI. *Appetite, 95*, 203-210.

Rogers, P. J., & Hardman, C. A. (2015). Food reward. What it is and how to measure it. *Appetite, 90,* 1–15.

Rollins, B.Y., Loken, E., & Birch, L.L. (2011). Preferences predict food intake from 5 to 11 years, but not in girls with higher weight concerns, dietary restraint, and % body fat. *Obesity, 19*(11), 2190-2197.

Ruddock, H. K., Dickson, J. M., Field, M., & Hardman, C. A. (2015). Eating to live or living to eat? Exploring the causal attributions of self-perceived food addiction. *Appetite, 95,* 262–268.

Schulte, E.M., Avena, N.M., & Gearhardt, A.N. (2015). Which foods may be addictive? The roles of processing, fat content, and glycemic load. *PloS One, 10*(2), e0117959.

Stunkard, A. J., & Messick, S. (1985). The Three-Factor Eating Questionnaire to Measure Dietary Restraint, Disinhibition and Hunger. *Journal of Psychosomatic Research, 29*(1), 71–83.

Thush, C., Wiers, R.W., Ames, S.L., Grenard, J.L., Sussman, S., & Stacy, A.W. (2008). Interactions between implicit and explicit cognition and working memory capacity in the prediction of alcohol use in at-risk adolescents. *Drug and Alcohol Dependence. 94*, 116–124.

Tuomisto, T., Hetherington, M. M., Morris, M.-F., Tuomisto, M. T., Turjanmaa, V., & Lappalainen, R. (1999). Psychological and Physiological Characteristics of Sweet Food “Addiction.” *International Journal of Eating Disorders*, *25(*2)*169*–175.

Vainik, U., Neseliler, S., Konstabel, K., Fellows, L. K., & Dagher, A. (2015). Eating traits questionnaires as a continuum of a single concept. Uncontrolled eating. *Appetite, 90*, 229–239.

Ziauddeen, H., Farooqi, I. S., & Fletcher, P. C. (2012). Obesity and the brain: how convincing is the addiction model? *Nature Reviews. Neuroscience, 13*, 279–286.

Tables

Table 1. *Descriptive statistics of sample by food addiction group. Values are means with standard deviations in parentheses.*

Variable	**Self-perceived food-addict**	**Non-addict**	***F*(df)**	***p***
N	31	29		
Age (y)	24.23(9.83)	23.59(9.02)	.07(1,58)	.794
BMI (kg/m^2)	24.30(4.66)	23.11(4.46)	1.01(1,58)	.320
BES	16.71(6.70)	9.69(5.02)	20.97(1,58)	<.001
TFEQ				
Disinhibition	9.42(2.91)	6.52(2.81)	15.42(1,58)	<.001
Restraint	7.10(4.88)	9.83(6.07)	3.71(1,58)	.059
YFAS symptom count	3.19(1.89)	1.45(0.87)	20.68(1,58)	<.001
Chi-Square			X^2	
YFAS diagnosis (N)	4	1	1.75(1)	.355

Table 2. *Means (standard deviations) for the three measures of food reward, for self-perceived food addicts and non-addicts, before and after consumption of the lunch meal. NA = not applicable.*

		Desire to Eat		**Willingness to Pay**		**Tapping (Operant task)**	
		Before	After	Before	After	Before	After
Chocolate	Addicts	83.48(12.36)	71.74(23.48)	26.68(23.07)	16.68(13.83)	270.26(119.30)	210.77(128.23)
	Non-addicts	82.62(15.00)	58.93(21.99)	25.76(21.24)	16.10(15.09)	246.00(129.47)	157.59(129.75)
Crisps	Addicts	82.48(13.00)	63.19(24.29)	22.74(20.19)	13.39(14.10)	NA	NA
	Non-addicts	71.34(20.16)	47.14(25.42)	17.59(15.03)	9.55(9.99)	NA	NA
Rice cakes	Addicts	52.39(27.47)	28.16(25.26)	9.65(10.36)	5.06(5.94)	NA	NA
	Non-addicts	41.55(25.22)	18.55(19.22)	8.45(10.32)	3.90(4.14)	NA	NA
Grapes	Addicts	77.48(17.38)	60.45(24.91)	20.19(16.32)	13.13(13.58)	244.65(120.50)	199.58(126.82)
	Non-addicts	77.69(15.50)	53.93(22.14)	19.97(17.66)	11.52(14.27)	247.72(125.21)	150.38(119.68)

Note. Desire-to-eat (*DtE) and willingness to pay (WtP) values represent scores (mm) provided on the corresponding 100mm Visual Analogue Scales. Tapping values represent the frequency of computer key taps within the allocated 1-minute time period in the operant response task.*

Table 3. *Results of regression analysis with measures of dietary restraint and disinhibition in step 1 and self-perceived food addiction in step 2. The dependent variable was total calories consumed.*

	B	**Std. Error**	**Beta**	**SR^2**	***p***
Step 1					
Constant	292.14	24.78			
Disinhibition	55.03	26.67	.254*	.07	.044
Restraint	-52.18	24.43	-.263*	.07	.037
Step 2					
Constant	242.04	39.19			
Disinhibition	27.41	31.25	.127	.01	.403
Restraint	-40.32	25.15	-.203	.04	.115
Self-perceived food addiction	97.91	59.91	.244	.05	.108

Note. R^2*=.134 for step 1,* R^2*=.173 for step 2,* R^2 *change=.039,p=.108, SR*^{2} *is the squared semi-partial correlation. *p<.05*

Table 4. *Results of regression analysis with measures of dietary restraint and disinhibition in step 1 and self-perceived food addiction in step 2. The dependent variable was mean overall DtE ratings (collapsed across conditions and foods).*

	B	**Std. Error**	**Beta**	**SR^2**	***p***
Step 1					
Constant	60.71	1.65			
Disinhibition	6.25	1.77	.423*	.18	.001
Restraint	-.63	1.62	-.046	.00	.700
Step 2					
Constant	59.13	2.65			
Disinhibition	5.37	2.11	.364*	.10	.014
Restraint	-.25	1.70	-.019	.00	.882
Self-perceived food addiction	3.09	4.05	.113	.01	.449

Note. R^2*=.181 for step 1,* R^2*=.190 for step 2,* R^2*change=.008, p=.449.* SR^2 *is the squared semi-partial correlation. *p<.05*

Figure Legends

Figure 1. Flow chart of the study procedure.

Figure 2. Number of calories consumed from chocolate and grapes, and total calories consumed, by self-perceived food addicts and non-addicts. *significant between-group difference, $p \leq .006$

Figure 3. Ratings of liking (panel A), and hunger (panel B) for self-perceived food addicts and non-addicts before and after the lunch meal. Liking ratings were averaged across all four test foods.

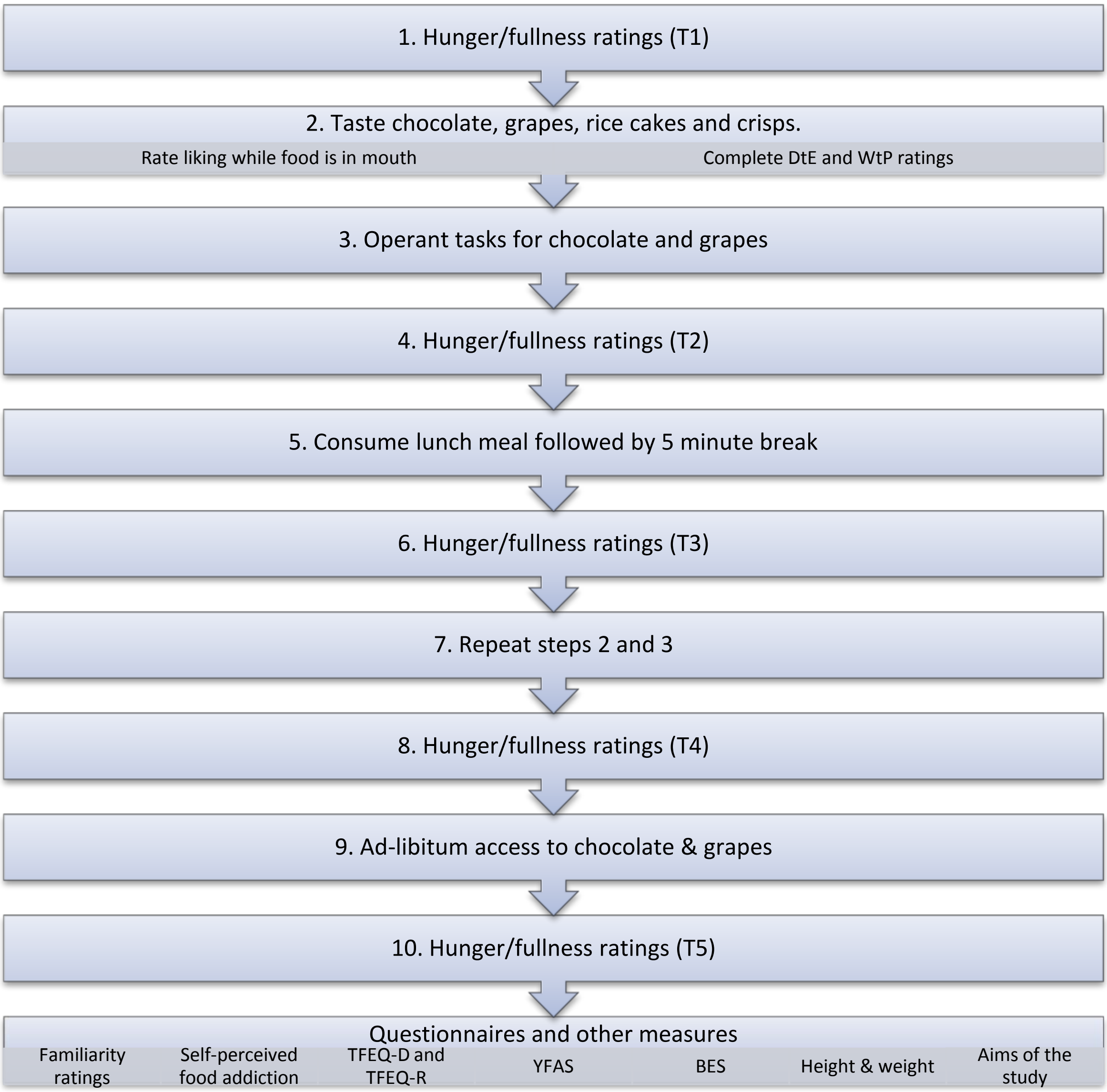
1. Hunger/fullness ratings (T1)
2. Taste chocolate, grapes, rice cakes and crisps.
Rate liking while food is in mouth
Complete DtE and WtP ratings
3. Operant tasks for chocolate and grapes
4. Hunger/fullness ratings (T2)
5. Consume lunch meal followed by 5 minute break
6. Hunger/fullness ratings (T3)
7. Repeat steps 2 and 3
8. Hunger/fullness ratings (T4)
9. Ad-libitum access to chocolate & grapes
10. Hunger/fullness ratings (T5)
Questionnaires and other measures
Familiarity ratings
Self-perceived food addiction
TFEQ-D and TFEQ-R
YFAS
BES
Height & weight
Aims of the study

Figure 1.

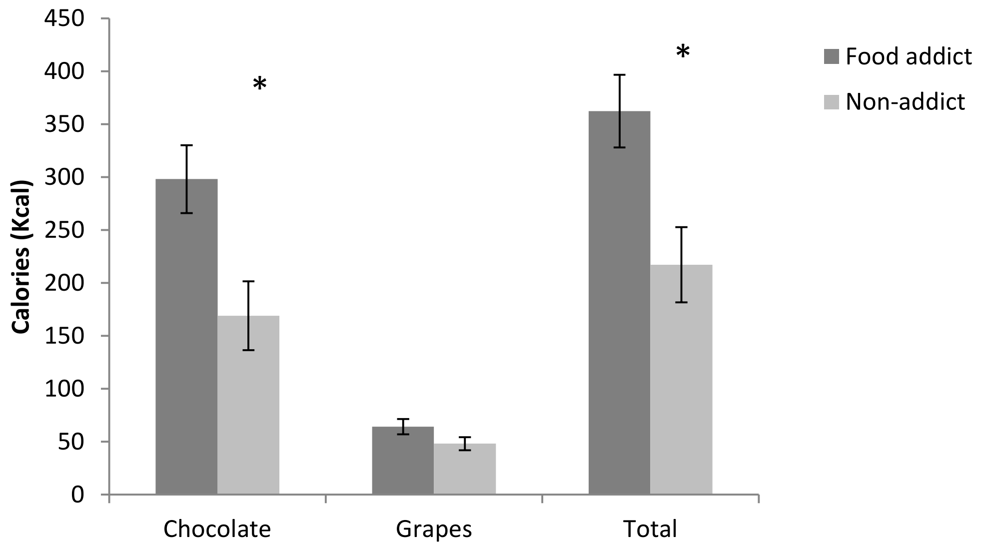
450
400
350
300
250
200
150
100
50
0
Calories (Kcal)
*
*
Chocolate
Grapes
Total
Food addict
Non-addict

Figure 2.

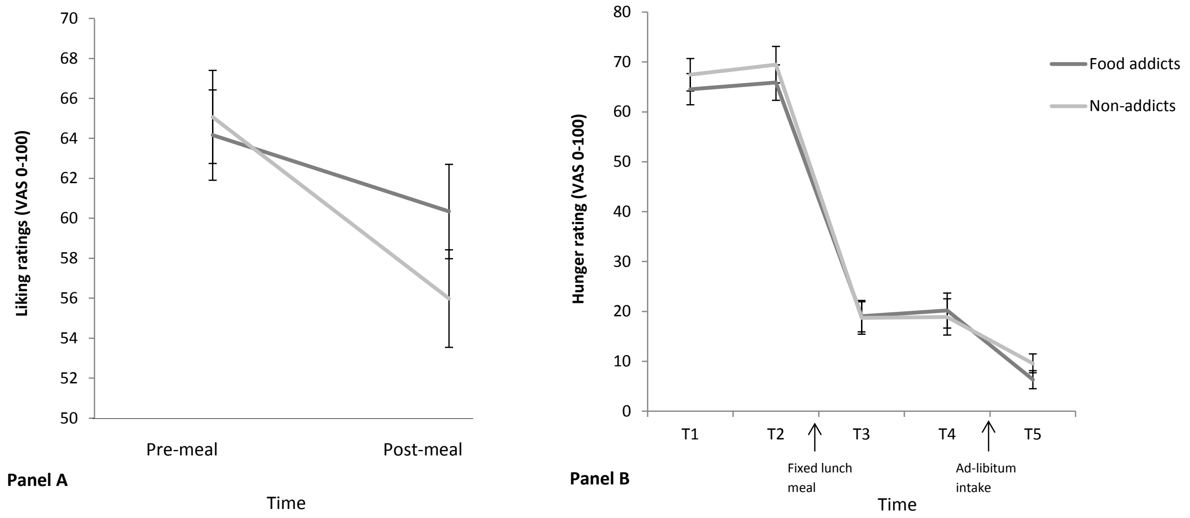
70
68
66
64
62
60
58
56
54
52
50
Liking ratings (VAS 0-100)
Pre-meal
Post-meal
Panel A
Time
80
70
60
50
40
30
20
10
0
Hunger rating (VAS 0-100)
Food addicts
Non-addicts
T1
T2
T3
T4
T5
Fixed lunch meal
Ad-libitum intake
Panel B
Time

Figure 3.

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