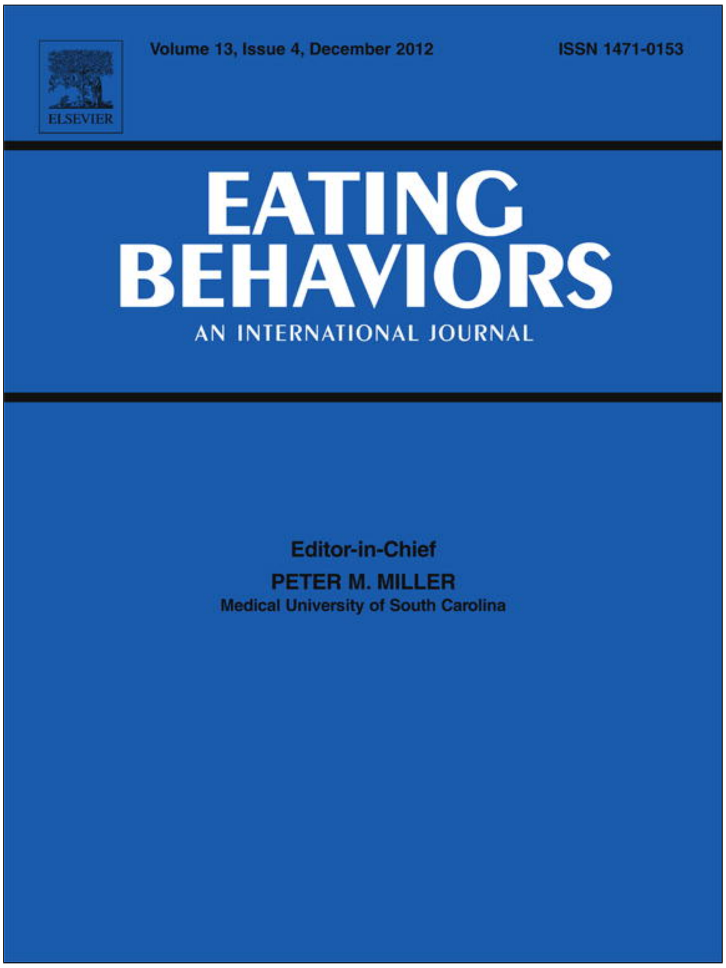
Volume 13, Issue 4, December 2012
ISSN 1471-0153
ELSEVIER
EATING BEHAVIORS
AN INTERNATIONAL JOURNAL
Editor-in-Chief
PETER M. MILLER
Medical University of South Carolina

Eating Behaviors 13 (2012) 423–428

Contents lists available at SciVerse ScienceDirect

Eating Behaviors

Women with elevated food addiction symptoms show accelerated reactions, but no impaired inhibitory control, in response to pictures of high-calorie food-cues

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ARTICLE INFO

Article history:
Received 16 April 2012
Received in revised form 24 July 2012
Accepted 27 August 2012
Available online 5 September 2012

Keywords:
Food addiction
Food-cues
Behavioral inhibition
Impulsivity

ABSTRACT

Addictive behaviors are accompanied by a lack of inhibitory control, specifically when individuals are confronted with substance-related cues. Thus, we expected women with symptoms of food addiction to be impaired in inhibitory control, when confronted with palatable, high-calorie food-cues. Female college students ($N = 50$) were divided in low and high food addiction groups based on the symptom count of the *Yale Food Addiction Scale*. Participants performed a Go/No-go-task with high-calorie food-cues or neutral pictures presented behind the targets. Self-reported impulsivity was also assessed. The high food addiction group had faster reaction times in response to food-cues as compared to neutral cues and reported higher attentional impulsivity than the low food addiction group. Commission and omission errors did not differ between groups or picture types. Hence, women with food addiction symptoms reported higher attentional impulsivity and reacted faster in response to food-cues, although neither increased self-reported motor impulsivity nor impaired behavioral inhibition was found. Food addiction symptoms seem to be related to attentional aspects of impulsivity but not other facets of impulsivity.

1. Introduction

Impulsivity has been found to be a prominent feature in substance abuse. By way of illustration, individuals with substance abuse display higher self-reported impulsivity and impulsive behaviors in a variety of experimental tasks (de Wit, 2009; Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001; Perry & Carroll, 2008). Such tasks often involve the assessment of motor response inhibition. Here, subjects are required to quickly respond to a frequently presented target and, thereby, the response becomes pre-potent. Responses to infrequent non-targets, however, have to be withheld (so-called *Go/No-go*-tasks). For instance, cocaine users showed inhibitory deficits in a Go/No-go-task, which involved distinct activation of frontal cortices (Garavan, Kaufman, & Hester, 2008; Garavan, Ross, Murphy, Roche, & Stein, 2002; Kaufman, Ross, Stein, & Garavan, 2003). Such behavioral disinhibition was even more pronounced in response to substance-related material in alcohol and polysubstance abusers (Noël et al., 2005, 2007).

In the past decade, accumulating evidence suggests that excessive eating may be similar to addictive behavior (e.g. Davis & Carter, 2009; Gearhardt, Corbin, & Brownell, 2009a; Meule, 2011; Pelchat, 2009), with some authors conceptualizing addictions as a syndrome with a common etiology but multiple opportunistic expressions including substance use disorder, pathological gambling, or excessive eating (Shaffer et al., 2004). Recently, Gearhardt et al. (2009b) introduced the *Yale Food Addiction Scale* (YFAS) to assess addictive symptoms related to eating behavior, thereby following the diagnostic criteria for substance dependence (Gearhardt, Corbin, & Brownell, 2009b). Accordingly, symptoms can be counted and can range between zero and seven. Moreover, food addiction can be diagnosed if at least three symptoms and a clinically significant impairment are present. Using this approach Gearhardt et al. (2011) could show that women with food addiction symptoms had elevated activation in reward circuitries, but also in frontal areas related to self-control, during anticipation of food intake. Furthermore, activation of inhibitory regions was reduced in response to food intake (Gearhardt et al., 2011).

Like other addictive behaviors, excessive eating has been related to impulsivity (Guerrieri, Nederkoorn, & Jansen, 2008). For instance, self-reported impulsivity is positively correlated with both body-mass-index (BMI) and the YFAS (Meule, Vögele, & Kübler, 2011, 2012a). At a behavioral level, overeating and binge eating are associated with decreased response inhibition (Jansen et al., 2009; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006; Nederkoorn, Van Eijs, & Jansen, 2004; Rosval et al., 2006). Like in patients with substance abuse, where behavioral disinhibition was particularly found in response to substance-related stimuli, behavioral disinhibition was enhanced in response to eating-related words in patients with bulimia (Mobbs, Van der Linden, d'Acremont, & Perroud, 2008).

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1471-0153/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.eatbeh.2012.08.001

Nevertheless, findings about the influence of food stimuli on behavioral inhibition are inconsistent. For example, Mobbs et al. (2011) could not replicate the finding that eating-related stimuli in particular increased behavioral disinhibition in patients with obesity and binge eating disorder, although this had been shown previously for patients with bulimia. Obese participants exhibited general deficits in response inhibition as compared to controls regardless if food or neutral stimuli were presented. Moreover, all participants, i.e. both patients and controls, made more commission errors in response to neutral words (i.e. when food words were the targets) as compared to food words (i.e. when neutral words were the targets) (Mobbs, Iglesias, Golay, & Van der Linden, 2011). In contrast, both obese and normal-weight participants committed more errors in response to food words (i.e. when neutral words were the targets) as compared to neutral words (i.e. when food words were the targets) in a study by Loeber et al. (2012). Finally, in our own studies we found increased behavioral inhibition in response to both food and neutral stimuli in restrained eaters as compared to unrestrained eaters after food intake (Meule, Lukito, Vögele, & Kübler, 2011). To conclude, studies that investigated the direct effects of exposure to food stimuli on behavioral inhibition either did not find any or even contradictory effects (i.e. impairment or enhancement).

Based on the similarities between addiction and excessive eating, we hypothesized that individuals with food addiction symptoms are impaired in response inhibition when confronted with food-related material. Therefore, we expected that women with multiple food addiction symptoms show decreased response inhibition, i.e. more commission errors in a Go/No-go-task, in response to food-cues compared to women with no or fewer food addiction symptoms. With regard to reaction times, it is unclear if presentation of substance- and eating-related stimuli leads to acceleration or slowing of responses in response to inhibition tasks (Loeber et al., 2012; Meule, Lukito, et al., 2011; Meule, Vögele, & Kübler, 2012b; Mobbs et al., 2008, 2011; Noël et al., 2005, 2007). Therefore, we had a non-directional hypothesis that reaction times in response to food-cues would differ from responses to neutral cues particularly in the high food addiction group. Finally, we expected that the high food addiction group would show higher self-reported impulsivity as measured with the short form of the Barratt Impulsiveness Scale (BIS-15) as compared to the low food addiction group.

2. Material and methods

2.1. Participants

Female participants were recruited among students at the University of Würzburg. Advertisements were posted on campus and distributed using a mailing list of a student council. Women who responded to the advertisements were contacted by phone ($N=82$) and screened for exclusion criteria which included mental disorders, psychoactive medication, under- or overweight (BMI <17.5 or >25 kg/m^2), and age >40 years. We decided to restrict the sample to women with normal-weight because only few participants of the screened sample were in the overweight range and, therefore, BMI distribution would have been skewed. A total of $n=50$ participants were included in the study. Mean age was $M=22.3$ years ($SD=3.0$; range: 19–32) and mean BMI $M=21.5$ kg/m^2 ($SD=2.7$). Participants either received course credits or € 20 for participation.[1]

[1] The reported data were part of a study that also included other tasks and physiological recordings on three occasions, which are reported elsewhere (cf. Meule, Lutz, Vögele, & Kübler, 2012b). The order of tasks was counterbalanced, i.e. subjects performed the XY-task either on the first, second, or third session. None of the stimuli used in the XY-task were used in the other tasks.

2.2. Questionnaires

2.2.1. Yale Food Addiction Scale (YFAS)

The YFAS (Gearhardt et al., 2009b) measures addictive eating behavior and consists of 27 items (e.g., "There have been times when I consumed certain foods so often or in such large quantities that I started to eat food instead of working, spending time with my family or friends, or engaging in other important activities or recreational activities I enjoy.", "I find that when certain foods are not available, I will go out of my way to obtain them. For example, I will drive to the store to purchase certain foods even though I have other options available to me at home.", or "Over time, I have found that I need to eat more and more to get the feeling I want, such as reduced negative emotions or increased pleasure."). The questionnaire is based on the diagnostic criteria for substance dependence of the DSM-IV (American Psychiatric Association, 1994). Validity of the YFAS has been indicated by positive associations with BMI, eating disorder symptomatology, emotional eating, food cravings, binge eating, difficulties in emotion regulation, and impulsivity in non-clinical samples and obese patients (Davis et al., 2011; Gearhardt et al., 2009b; Gearhardt et al., 2012; Meule, 2012; Meule, Heckel, & Kübler, 2012; Meule & Kübler, 2012; Meule et al., 2012a). Internal consistency of the German version is $\alpha=.81$ (Meule et al., 2012a) and was $\alpha=.83$ in the current study.

2.2.2. Center for Epidemiologic Studies Depression Scale (CES-D)

The CES-D (Radloff, 1977) was used to assess whether high versus low food addiction participants differed in depressive symptoms during the past week. Validity of the CES-D has been shown by high positive correlations with other measures for depression, e.g. the Beck Depression Inventory or interviewer ratings, and personality variables, e.g. neuroticism or trait anxiety (Hautzinger, 1988; Orme, Reis, & Herz, 1986; Radloff, 1977). Internal consistency of the German version varies between $\alpha=.85$–$.91$ (Hautzinger, 1988) and was $\alpha=.90$ in the current study.

2.2.3. Barratt Impulsiveness Scale — Short Version (BIS-15)

The BIS-15 was proposed by Spinella (2007) as short version of the BIS-11 (Patton, Stanford, & Barratt, 1995) for the measurement of impulsivity. Instead of 30 items as in the long version, it consists of 15 items only. The three-factor solution on the dimensions *motor*, *attentional*, and *non-planning impulsivity* could also be confirmed for the German version (Meule, Vögele, & Kübler, 2011). Convergent validity of the BIS-15 has been shown by moderate to strong relationships with the Frontal Systems Behavior Scale and the UPPS Impulsive Behavior Scale while discriminant validity has been indicated by weak correlations with sensation seeking (Meule, Vögele, et al., 2011; Spinella, 2007). Internal consistency of the German version is $\alpha=.81$ (Meule, Vögele, et al., 2011). In the current study, internal consistency was $\alpha=.79$ and ranged between $\alpha=.68$–$.82$ for the subscales.

2.2.4. Food Cravings Questionnaires — State Version (FCQ-S)

The FCQ-S (Cepeda-Benito, Gleaves, Williams, & Erath, 2000) was used to measure current food cravings. This 15-item questionnaire assesses momentary food cravings on the dimensions *intense desire to eat*, *anticipation of positive reinforcement that may result from eating*, *anticipation of relief from negative states and feelings as a result of eating*, *lack of control over eating*, and *craving as a physiological state* (Cepeda-Benito et al., 2000). Validity of the FCQ-S has been indicated by positive associations with length of food deprivation and current negative affect (Cepeda-Benito, Fernandez, & Moreno, 2003; Meule, Lutz, Vögele, & Kübler, 2012a). Moreover, the FCQ-S has been found to be sensitive to meal consumption and food-cue exposure such that state cravings decreased after breakfast (Cepeda-Benito et al., 2000; Vander Wal, Johnston, & Dhurandhar, 2007) and increased after performing a cognitive task involving food pictures (Meule, Skirde, Freund, Vögele, & Kübler, 2012). Subscales are highly inter-correlated and internal consistency of the total score is α = .92 (Meule, Lutz, et al., 2012a). Therefore, we only used the total score for our analyses and internal consistency was α = .90 in the current study.

2.3. XY-task

A modification of the XY-task (Garavan et al., 2002; Meule, Lukito, et al., 2011) was used in this study. The program was compiled using E-prime 2.0 (Psychology Software Tools Inc., Pittsburgh, PA) and displayed on a LCD TFT 22″ screen. In this task, participants were required to press a button in response to every target (i.e. the letters X and Y) that was different from the preceding one. When the same target appeared consecutively, the response had to be withheld (= No-go-trials). In addition, pictures of either high caloric food (F) or neutral objects (N) were presented behind the targets (Fig. 1). Food items were pictures of high caloric sweet and savory foods, which were selected from a set of pictures previously used (Blechert, Feige, Hajcak, & Tuschen-Caffier, 2010; Blechert, Feige, Joos, Zeeck, & Tuschen-Caffier, 2011; Meule, Lukito, et al., 2011). Neutral pictures were common household items. All pictures were edited to be homogeneous with respect to background color. The task was separated into four counterbalanced blocks (F–N–F–N or N–F–N–F). Each block consisted of 315 trials including 20 no-go-trials. A practice block of 80 trials without any pictures behind the targets was presented prior to the experimental blocks. The whole task lasted for approximately 20–30 min. Reaction times (ms) in Go-trials and the number of commission and omission errors were recorded as outcome measures.

2.4. Procedure

All participants were asked not to consume food, caffeine, nicotine, or alcohol at least 3 h before the experiment. After participants had performed the XY-task, they immediately filled out the FCQ-S and reported the hours that had elapsed since their last meal. Completion of the other questionnaires and measurement of participants' height and weight were conducted either on the same day or within 1–2 weeks after the experiment, depending on individual assignment to experimental conditions.[1]

2.5. Data analysis

Participants were divided in low ($n = 30$) and high food addiction groups ($n = 20$) based on a median split of the YFAS symptom count ($Mdn = 1$). Participants with ≤1 food addiction symptoms were included in the low food addiction group. In this group, 83.3% ($n = 25$) endorsed one symptom and 16.7% ($n = 5$) reported no symptom. Mean food addiction symptom count was $M = .83$ ($SD = .38$) in the low food addiction group and $M = 2.65$ ($SD = .75$; range: 2–4 symptoms) in the high food addiction group. Groups were compared for age, BMI, hours since the last meal, current food cravings (FCQ-S), food addiction symptoms (YFAS), depressive symptoms (CES-D), and impulsivity (BIS-15) using *t*-tests. In addition, we calculated correlations between food addiction symptoms and those variables.

Measures of interest in the XY-task were reaction times (RTs) and omission errors (OEs), which should reflect attentional processes, and commission errors (CEs) as an indicator for inhibitory control. Trials with an RT of less than 150 ms, reflecting anticipation, were excluded from analyses. A 2 (picture type) × 2 (group) ANOVA for repeated measures was calculated for each of the dependent variables. Post-hoc *t*-tests (Bonferroni-adjusted) were calculated in case of significant interactions.

3. Results

3.1. Participant characteristics

Participants in the high food addiction group were younger ($M = 21.15$ years, $SD = 1.81$) and reported higher levels of self-reported attentional impulsivity ($M = 10.10$, $SD = 2.10$) compared to the low food addiction group (age: $M = 23.10$ years, $SD = 3.44$, $t_{(48)} = 2.33$, $p < .05$; attentional impulsivity: $M = 8.70$, $SD = 2.45$, $t_{(48)} = -2.09$, $p < .05$). Self-reported attentional impulsivity was also positively correlated with food addiction symptoms ($r = .34$, $p < .05$). Using age and

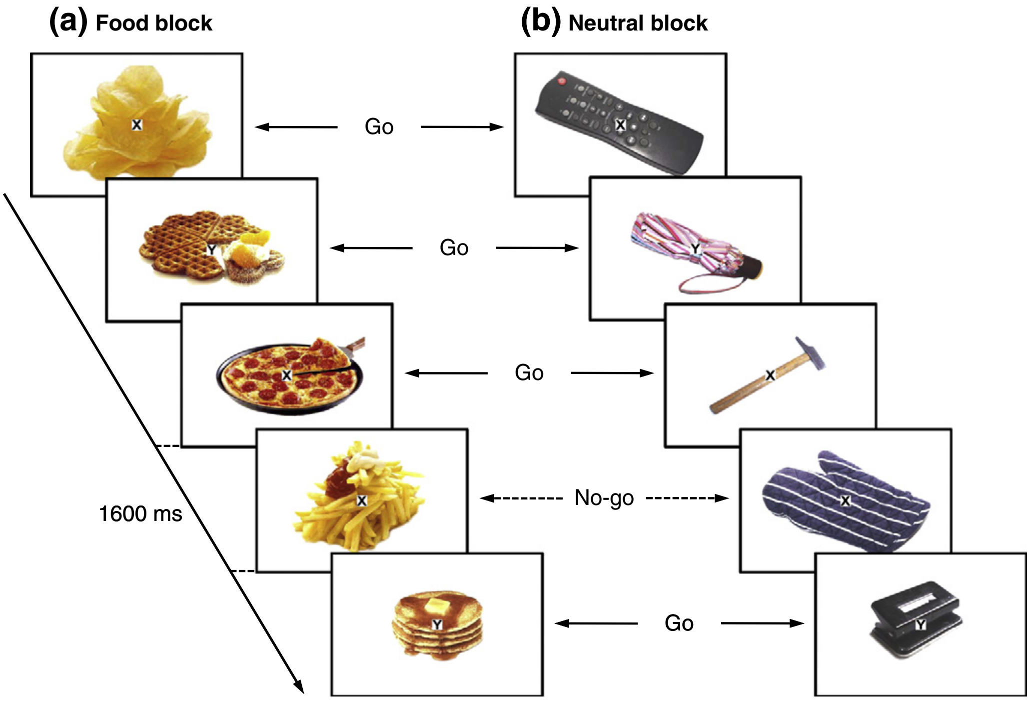

Fig. 1. XY-task with representative screen displays from a (a) food and (b) neutral block. Targets were presented for 600 ms. Either a blank screen or a feedback, in the case of a false reaction, was presented for 1000 ms during the inter-trial interval.

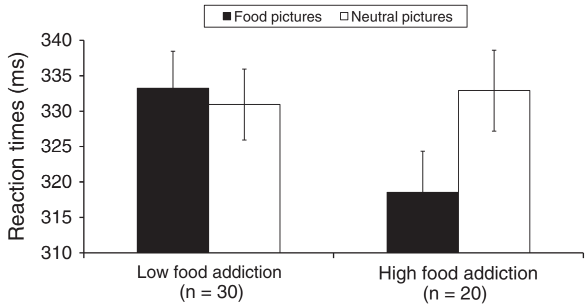

Fig. 2. Mean reaction times in the XY-task as a function of food addiction symptoms and picture type. Participants were divided in low (≤1 food addiction symptom) and high food addiction groups (>1 food addiction symptom) based on YFAS scores. Error bars indicate the standard error of the mean.

attentional impulsivity as covariates in the subsequent analyses of task performance did not change results. Groups did not differ in BMI ($t_{(48)}=-1.52$, $p>.05$), current food cravings ($t_{(48)}=-.30$, $p>.05$), hours since the last meal ($t_{(48)}=.63$, $p>.05$), depressive symptoms ($t_{(48)}=-1.87$, $p>.05$), self-reported motor impulsivity ($t_{(48)}=-.86$, $p>.05$) and self-reported non-planning impulsivity ($t_{(48)}=-.25$, $p>.05$). Although group differences were non-significant, food addiction symptoms were positively correlated with BMI ($r=.42$, $p<.01$) and depressive symptoms ($r=.29$, $p<.05$).

3.2. Task performance

3.2.1. Reaction times

Mean RTs in Go-trials were $M=329.67$ ms ($SD=25.24$). There was no main effect for group ($F_{(1,48)}=.75$, $p>.05$). A significant main effect for picture type ($F_{(1,48)}=4.78$, $p<.05$, $\eta^2_p=.09$) indicated that participants reacted faster in blocks with food pictures ($M=327.38$ ms, $SD=28.21$) than in blocks with neutral pictures ($M=331.73$ ms, $SD=26.45$). The interaction between group and picture type was significant ($F_{(1,48)}=9.17$, $p<.01$, $\eta^2_p=.16$). Post-hoc tests revealed that only in the high food addiction group participants reacted faster in response to food ($M=318.56$ ms, $SD=25.96$) as compared to neutral cues ($M=332.90$ ms, $SD=25.54$, $t_{(19)}=-3.43$, $p<.01$). Reaction times did not differ between picture types in the low food addiction group ($t_{(29)}=.66$, $p>.05$; Fig. 2).[2]

3.2.2. Commission errors

Mean number of CEs was $M=52.26$ ($SD=14.03$). There were neither significant main effects for group ($F_{(1,48)}=.21$, $p>.05$) and picture type ($F_{(1,48)}=.01$, $p>.05$) nor a significant interaction group × picture type ($F_{(1,48)}=.58$, $p>.05$).

3.2.3. Omission errors

Mean number of OEs was $M=27.04$ ($SD=27.54$). There were neither significant main effects for group ($F_{(1,48)}=2.04$, $p>.05$) and picture type ($F_{(1,48)}=1.42$, $p>.05$) nor a significant interaction group × picture type ($F_{(1,48)}=1.83$, $p>.05$).

4. Discussion

In the present study, we found that women with symptoms of food addiction responded faster to high-calorie food-cues as compared to neutral cues. No such difference was observed in women with no or only one food addiction symptom. Our hypothesis of a differential effect of food-cues on behavioral inhibition as evidenced by commission errors in the XY-task could not be confirmed. Women with food addiction symptoms reported heightened levels of attentional impulsivity while no group differences in self-reported motor and non-planning impulsivity were found.

The finding of accelerated reaction times in response to pictorial food stimuli in women with food addiction symptoms corresponds to findings of studies in which comparable samples were investigated. For example, faster detection of food-related words and pictures has been found for restrained eaters (Boon, Vogelzang, & Jansen, 2000; Hollitt, Kemps, Tiggemann, Smeets, & Mills, 2010; Meule, Vögele, & Kübler, 2012b) and chocolate cravers (Smeets, Roefs, & Jansen, 2009). In contrast, restrained eaters or chocolate cravers who have been pre-exposed to craving-inducing food or food-cues have been shown to respond more slowly in such tasks (Green, Rogers, & Elliman, 2000; Kemps, Tiggemann, & Grigg, 2008; Meule, Lukito, et al., 2011; Smeets et al., 2009). Longer reaction times have also been found in individuals with substance use as a result of drug craving or drug exposure (Baxter & Hinson, 2001; Cepeda-Benito & Tiffany, 1996; Sayette & Hufford, 1994; Sayette et al., 1994).

In our study, groups did not differ with respect to craving. We would argue that in cognitive tasks that involve simple reactions, pre-exposure to food and thereby induced craving leads to slowed reactions (i.e. distraction) in response to food-cues, similar to slowed reactions after drug exposure and drug craving. On the other hand, if there is no pre-exposure or craving induction, as was the case in the present study, accelerated reactions to high-calorie food-cues can be found. Smeets et al. (2009) interpreted their results such that faster detection of food-cues could be the result of increased incentive salience in chocolate cravers. A similar conclusion has been drawn for cognitive bias to food-cues in eating disorder patients and restrained eaters (Brooks, Prince, Stahl, Campbell, & Treasure, 2011). Accordingly, we speculate that shortened reaction times in our study may be a behavioral equivalent to increased activation of the reward system in women with food addiction symptoms, when they are confronted with highly palatable food-cues (Gearhardt et al., 2011).

In the study by Gearhardt et al. (2011), however, activation of the reward system during food-exposure, but before food intake, was accompanied by activation of inhibitory areas of the brain. The authors speculated that women with food addiction symptoms "may respond to increased appetitive motivation for food by attempting to implement self-control strategies" (Gearhardt et al., 2011, p. 812). Hence, this activation pattern might account for the lack of difference in commission errors between groups in the present study.

Another possibility that might account for the lack in differences in behavioral inhibition could be failure of the task to produce enough commission errors. Nevertheless, the mean number of commission errors made closely corresponded to, and was even higher compared with our previous study in which we used this task (cf. Meule, Lukito, et al., 2011).

A third possibility could be that food addiction is related to attentional impulsivity rather than motor impulsivity. This line of argument would be supported by our questionnaire data. This conclusion, however, should be drawn only with reservation, as there is generally only a negligible relation between self-reported impulsivity and laboratory tasks (Cyders & Coskunpinar, 2011). Accordingly, attentional impulsivity was unrelated to reaction times in our study.

The current study has several limitations. Firstly, sample size was rather small and the high food addiction group consisted of merely 20 participants. Moreover, diagnoses of food addiction were rare. Individuals in this group only showed a tendency towards food addiction, and can, therefore, not be taken as representing the full diagnosis of

[2] To further validate this finding, we correlated reaction times with the symptom count of the YFAS. The amount of food addiction symptoms was negatively correlated with reaction times in response to food-cues ($r=-.35$, $p<.05$), but not with reaction times in response to neutral cues ($r=-.04$, $p>.05$).

food addiction. This might have resulted in a lack of differences in behavioral inhibition and also in self-reported motor impulsivity. Also, we investigated a sample of female college students, which may not be representative of the general population. Future studies should investigate obese samples in which food addiction diagnoses are more prevalent (Meule, 2011). Secondly, it has to be noted that our concurrent picture presentation might have interfered with pure response inhibition, because of additional attentional requirements. A possible solution would be to use food pictures as targets, instead of presenting them behind targets, similar to studies that used food-related words (e.g. Loeber et al., 2012). Thirdly, future studies may investigate actual eating behavior in the presence of food in individuals with an addiction-like eating behavior. The sight and smell of real food may lead to a disinhibition of eating in this population which may not be observed in motor response inhibition tasks using pictorial food stimuli.

In summary, this study showed that food addiction symptoms are related to accelerated responses to high-calorie food-cues as well as heightened self-reported attentional impulsivity. As outlined above, we would argue that faster reactions to pictorial high-calorie food-cues reflect an automatic approach bias associated with incentive salience. This interpretation would be supported by results on associations between impulsivity, external eating, reward sensitivity, and attentional bias to food-cues (Hou et al., 2011). In contrast, food addiction symptoms are not accompanied by behavioral disinhibition in response to pictures of high-calorie food-cues and self-reported motor impulsivity, highlighting the importance of affective reactions beyond inhibitory control in eating behavior. For example, although general inhibitory control moderated food intake, automatic positive affective reactions towards candy were a more important predictor of candy consumption in a study by Hofmann et al. (2009).

A clinical implication of those findings is that individuals with food addiction symptoms may benefit from attentional retraining aiming at a reduction of food-cue sensitivity. Recent evidence suggests that cognitive bias modification procedures are effective in changing attentional bias as well as reducing symptoms in mental disorders, including eating- and addiction-related problems (MacLeod, 2012). For instance, studies that investigated the effects of a retraining of automatic action tendencies, e.g., by pairing food- or alcohol-related stimuli with a stopping response, found a reduction of food or alcohol intake (Houben, 2011; Houben, Havermans, Nederkoorn, & Jansen, 2012; Houben & Jansen, 2011; Houben, Nederkoorn, Wiers, & Jansen, 2011). Possible mechanisms underlying this behavioral change may be a decrease of positive implicit attitudes and automatic approach bias towards these stimuli, respectively (Houben et al., 2012; Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011). Future studies should investigate whether such a procedure will alter reactions to food-cues, thereby reducing symptomatology in individuals presenting with addiction-like eating behavior.

Role of funding sources

Funding for this study was provided by a grant of the research training group 1253/2 which is supported by the German Research Foundation (DFG) by federal and Länder funds. DFG had no role in the study design, collection, analysis or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Contributors

All authors contributed to the design of the study. Annika Lutz collected the data. Data analyses were performed by Annika Lutz and Adrian Meule who also wrote the first draft of the manuscript. Claus Vögele and Andrea Kübler contributed to interpretation of the data and manuscript preparation. All authors have approved the final manuscript.

Conflict of interest

Neither author has any conflicts of interest.

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