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A sad mood increases attention to unhealthy food images in women with food addiction

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ABSTRACT

Food addiction and emotional eating both influence eating and weight, but little is known of how negative mood affects the attentional processes that may contribute to food addiction. The purpose of this study was to compare attention to food images in adult women ($N = 66$) with versus without food addiction, before and after a sad mood induction (MI). Participants' eye fixations were tracked and recorded throughout 8-s presentations of displays with healthy food, unhealthy food, and non-food images. Food addiction was self-reported using the Yale Food Addiction Scale. The sad MI involved watching an 8-min video about a young child who passed away from cancer. It was predicted that: (1) participants in the food addiction group would attend to unhealthy food significantly more than participants in the control group, and (2) participants in the food addiction group would increase their attention to unhealthy food images following the sad MI, due to increased emotional reactivity and poorer emotional regulation. As predicted, the sad MI had a different effect for those with versus without food addiction: for participants with food addiction, attention to unhealthy images increased following the sad MI and attention to healthy images decreased, whereas for participants without food addiction the sad MI did not alter attention to food. These findings contribute to researchers' understanding of the cognitive factors underlying food addiction.

The idea that certain foods may have addictive properties has received a great deal of attention during the past decade. Food items that are high in fat and sugar are thought to activate reward systems in the brain related to substance abuse (e.g., Avena, Rada, & Hoebel, 2008; Liang, Hajnal, & Norgren, 2006). Research in animals has found that consumption of both fat and sugar lead to a release of dopamine, producing a "feel good" effect (Avena, Bocarsly, & Hoebel, 2012). Fortuna (2012) has proposed that food addiction and drug addiction may be similar in terms of cravings and disinhibition/tolerance. For example, when shown an image of a chocolate milkshake, women self-described as "food addicts" exhibited brain activation in areas such as the anterior cingulate gyrus and the amygdala, areas also implicated in drug cravings (Gearhardt et al., 2011). Gearhardt et al. also found that women with food addiction experienced decreased inhibitory control in response to the reward cue of a chocolate milkshake image, as reflected by lower activation in the orbitofrontal cortex, a pattern also observed in problem drug users. These findings suggest that individuals with food addiction may exhibit attentional biases for food or food-related stimuli, such as images of food, due to their rewarding nature. The observation that individuals with food addiction attend to food differently than controls would be consistent with this prediction, but few studies have examined attentional biases in those with food addiction.

1. Attentional biases to food

There is evidence that both overweight/obese individuals and individuals with disordered eating exhibit attentional biases for food. Gearhardt, Treat, Hollingworth, and Corbin (2012) compared attention to food images in overweight and obese women using a visual search task, while also manipulating hunger levels. The images ranged from high fat, high sugar foods such as cupcakes and ice cream, to low fat, low sugar foods such as vegetables and lean meats. They found that higher levels of hunger led to increased attention to sweet foods, as well as to fried, fatty foods. This finding suggests that attentional biases for unhealthy foods may influence

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one's ability to make healthy food choices and thereby maintain a healthy weight. In a related study, Bongers et al. (2015) found that participants with obesity exhibited attentional biases for high-calorie food images. Specifically, highly impulsive participants with obesity were faster to detect high-calorie foods than their highly impulsive, normal weight peers. No differences in detection times were observed between low-impulsive obese and normal weight participants. There were also no differences in detection times for low-calorie foods. These results have implications for attentional biases in food addiction, as food addiction has been associated with increased impulsivity (Gearhardt et al., 2011).

Attentional biases for food have also been observed in individuals with binge eating. Popien, Frayn, von Ranson, and Sears (2015) used eye gaze tracking to compare fixations to food in a non-clinical sample of individuals of normal weight with and without recent binge eating. Participants viewed images of real-world scenes (restaurants, kitchens, offices, etc.) for 8 s, some of which contained high-calorie or low-calorie food. They found that adults with binge eating symptoms attended to both high- and low-calorie food significantly more than control participants. Participants with binge eating symptoms also fixated on food earlier than control participants, suggesting a hypervigilance to food. Schag et al. (2013) used eye-gaze tracking to measure attention to pairs of food and non-food images in individuals with binge eating disorder (BED) and found that overweight and obese participants with BED fixated on food longer than overweight and obese participants without BED and normal-weight participants without BED. Because food addiction and binge eating are often comorbid (Gearhardt, White et al., 2012), individuals with food addiction may exhibit similar attentional biases as those with BED, although to date no studies have specifically examined this possibility.

2. Mood and eating

Anecdotally, many individuals report turning to food as a comfort and coping mechanism to reduce negative emotion, and some research has supported this association (e.g., Kenardy, Butler, Carter, & Moor, 2003; van Strien et al., 2013). For example, van Strien et al. found that female university students with emotional eating increased their consumption of sweet foods following a negative mood induction (MI), although there was no increase in the consumption of salty foods. On the other hand, using similar female undergraduate student samples, several studies have not found an association between self-reported emotional eating and increased food consumption in response to a negative mood (e.g., Adriaanse, de Ridder, & Evers, 2011; Brogan & Hevey, 2013; Werthmann et al., 2014).

For individuals with disordered eating, and specifically binge eating, low mood is consistently linked to increased food consumption. The affect-regulation hypothesis of binge eating proposes that binges are often preceded by negative emotions and that the purpose of binge eating is to reduce these emotions (Hawkins & Clement, 1984). Bruce and Agras (1992) found that binge eating was most often triggered by depressed mood or boredom/loneliness. Vanderlinden et al. (2004) found that negative emotions and cognitions were reported prior to binge eating episodes. In laboratory settings, inducing a negative mood increases food intake and binge eating episodes in those with binge eating (e.g., Chua, Touyz, & Hill, 2004; Telch & Agras, 1996). Finally, research using ecological momentary assessment, which involves repeated brief ratings of affect, has confirmed that negative affect is a consistent antecedent of binge eating (e.g., Haedt-Matt & Keel, 2011). Given the interaction between negative affect and binge eating, an examination of the interaction between negative affect and eating in food addiction may lead to important insights into this condition.

3. Food addiction, mood, and attention

To our knowledge, despite the associations between binge eating and food addiction, no study has yet examined attention to food in individuals with food addiction. Moreover, although mood and emotional eating are strongly implicated in binge eating, their relationship in food addiction is not well understood. We note that the Yale Food Addiction Scale (YFAS; Gearhardt, Corbin, & Brownell, 2009), a self-report measure of food addiction, has many items related to emotional responses to food and eating. For example, item 21 asks participants whether food reduces negative emotions or increases pleasurable feelings, essentially describing emotional eating, although the YFAS conceptualizes this phenomenon as drug tolerance ("I have found that eating the same amount of food does not reduce my negative emotions or increase pleasurable feelings the way it used to").

Several studies have reported associations between emotion and food addiction, although they have not examined emotional eating specifically. Gearhardt, White et al. (2012) found that food addiction was associated with poorer emotion regulation skills, an important finding given that emotion regulation skills are thought to mediate the impact of emotional eating tendencies on food consumption (Evers, Stok, & de Ridder, 2010). Consistent with this idea is the fact that Davis et al. (2011) found that individuals with food addiction exhibited greater emotional reactivity relative to obese controls. For these reasons an experimental investigation of the impact of negative affect in those with food addiction will contribute to a better understanding of the relationships among food addiction, emotion, and attention.

4. The present study

The purpose of the present study was to examine attention to food in women with food addiction, before and after a sad MI. Only women were recruited for the study, given evidence that they are more emotionally responsive in their eating than men (e.g., Kenardy et al., 2003). Unlike previous MI studies where participants were randomly assigned to either a neutral or a sad MI, in this study both types of MIs were administered to all participants to eliminate between-group variation confounded with the MI assignment and to create a more sensitive within-subjects test of the sad MI effect. Groups were created based on participants' meeting criteria for food addiction, as defined by the Yale Food Addiction Scale (YFAS; Gearhardt et al., 2009), an individual difference that has not been examined in relation to emotion and attention to food in previous research. Our study differed from previous studies that used variations of the dot-probe task (e.g., Schag et al., 2013), as we did not present pairs of food and non-food images for a few seconds (images are presented for 1–3 s in most studies). Instead, we presented displays of four images (one unhealthy food image, one healthy food image, and two non-food images) for 8 s so that we could measure participants' attention to food and non-food images when they competed for attention over this interval. A longer display duration also allowed us to determine if the sad MI would produce changes in participants' immediate attention to the images and in their more sustained attention. By evaluating attention to food stimuli over a longer interval, and with more complex displays, our study expands on previous research and increases the generalizability of the findings reported in this literature.

The main hypotheses were: (1) individuals with food addiction would attend to unhealthy food more than individuals without food addiction, regardless of their mood state, because unhealthy food is postulated to be more "addictive" and thus more salient and rewarding, and (2) individuals with food addiction would increase their attention to unhealthy food in response to the sad

MI, due to their higher emotional reactivity and poorer emotional regulation.

5. Method

5.1. Participants

The women who participated in the study included undergraduate students recruited through an online research participation system and individuals recruited via advertisements placed on campus. The study received approval from an institutional research ethics board and all participants provided informed consent. Participants received bonus credit in a psychology course or a $25 gift card in exchange for their participation in the study. Participants were provided with detailed instructions outlining the study procedure at the time of their lab visit. They were not asked to refrain from eating or drinking prior to their visit. Participants were classified into the food addiction or control group according to criteria described below. Descriptive statistics for each group are shown in Table 1. Participants were fully debriefed at the end of the study session and provided with information on eating disorders, body image, and contact information for local agencies offering free services.

5.2. Measures

Potential participants were identified using the Yale Food Addiction Scale (YFAS) and a demographics questionnaire, which were completed online via Survey Monkey (www.surveymonkey.com). The YFAS consists of 27 questions, 16 that assess the frequency of behaviors such as overeating and the experience of withdrawal symptoms, 8 yes/no questions that assess the impact of eating behaviors and success of trying to cut down on certain foods, and 3 questions that assess which foods the respondent finds problematic (Gearhardt et al., 2009). The YFAS has been reported to have adequate internal reliability and convergent, discriminant, and incremental validity among undergraduates (Gearhardt et al., 2009). A total of 86 individuals were sent the online survey after responding to campus advertisements, and 48 were invited for a lab visit because they had high scores on the YFAS (38 responded and participated in the study). A total of 112 undergraduate students completed the survey using the online research participation system and 18 were invited for a lab visit based on their high scores on the YFAS (9 responded and participated in the study). The participants in the control group were also recruited from among the students who completed the survey using the online research participation system.

During their lab visit, participants completed the YFAS, the Eating Disorder Examination Questionnaire (EDE-Q 6.0; Fairburn & Beglin, 1994), and the Emotional Eating Scale (EES; Arnow, Kenardy, & Agras, 1995). These measures were completed after the eye-tracking data collection in order to minimize potential expectancy effects on participants' attention to food images. Scores on the second administration of the YFAS during the lab visit were used to create the food addiction and control groups. The criteria used to classify the two groups were as follows: (1) the food addiction group was composed of participants who endorsed three or more symptoms and distress and impairment on the YFAS, thus meeting this measure's criteria for food addiction (2) the control group was composed of participants who scored 2 or lower on the YFAS and did not endorse distress or impairment. This food addiction "diagnosis" is consistent with the DSM-IV substance dependence criteria (American Psychiatric Association, 2000) and is the method of scoring the YFAS suggested by Gearhardt et al. (2009). These criteria have also been used in other studies of food addiction (e.g., Gearhardt, White et al., 2012; Meule, Heckel, & Kubler, 2012).

The EDE-Q was administered to assess eating disorder psychopathology. It consists of 28 questions that assess eating behaviors, compensatory behaviors, and body image, as well as body weight and height (Fairburn & Beglin, 1994). EDE-Q scales have been shown to have adequate internal consistency and test-retest reliability for each of the four subscales (Berg, Peterson, Frazier, & Crow, 2012). For the EES, participants are asked to identify the extent to which a list of 25 emotions stimulate a desire to eat, from "no desire" to an "overwhelming urge", which is coded into a 5-point scale (Arnow et al., 1995). The EES anxiety subscale has been associated with increased food intake (Schneider et al., 2012).

Participants were asked to rate their levels of hunger and satiety using visual analogue scales ranging from 0 to 100. Participants provided demographic information, including their weight and height, from which BMI was calculated. As noted previously, all of these measures were completed after the eye-tracking data were collected.

Table 1
Participant demographics for the food addiction and control groups.

	Food addiction group ($N = 31$)		Control group ($N = 35$)	
	M	*SD*	*M*	*SD*
Age, yrs	25.45_a	10.90	19.71_b	1.91
Body Mass Index (BMI), kg/m^2	26.12_a	6.93	22.28_b	3.66
Caucasian (%)	48.40_a	–	57.10_a	–
Hunger Ratings	55.26_a	30.93	47.79_a	23.94
Satiety Ratings	38.90_a	31.50	45.94_a	23.42

Note: Means with different subscripts differ at $p < .05$ in a t-test or chi-square comparison, as appropriate.

5.3. Measures of mood

Participants' mood states were assessed using two different measures at seven points during the study, whenever there was a change in task (e.g., between the sad MI procedure and the eye tracking). The first measure was the Visual Analogue Mood Scale (VAMS; Luria, 1975), which is a widely used measure of mood change in studies using mood induction procedures (e.g., Ahearn, 1997; Scherrer & Dobson, 2015; Segal et al., 2006). It consists of a 100 mm horizontal line with the left side labeled "very sad" and the right side labeled "very happy". Participants are asked to indicate their mood by placing a tick mark on the line. This mark is scored from 0 to 100 by measuring its distance in mm from the left side. The VAMS has good psychometric properties with respect to validity and reliability (e.g., Blackburn, Cameron, & Deary, 1990; Brosse, Craighead, & Craighead, 1999; Segal, Gemar, & Williams, 1999, 2006). The second measure of mood was an 11-point horizontal scale ranging from −5 (labeled *very negative*) to + 5 (labeled *very positive*), with a midpoint of 0 (labeled *neutral*). This measure was used by Newman and Sears (2015) in their study of the effect of a sad mood on attention to emotional images in remitted depressed individuals and was found to be highly correlated with the VAMS. Two different measures of mood were used to enhance the sensitivity of the mood change assessment (pre-sad MI vs. post-sad MI) given its importance in the study (e.g., it was important to assess whether the sad MI was equally effective for the two groups, in order to determine if any differences in attention between the groups could be explained by a difference in the efficacy of the sad MI). Each time participants rated their mood they used both of these measures.

5.4. Mood induction procedure

The neutral MI was an instructional video describing how to install an electrical power receptacle ("Electrical Help: How to Install a Power Receptacle", essortment, 2012). This video was chosen for its factual, non-emotional content and was approximately 5 min in duration (similar in duration to the video shown in the sad MI). The sad MI also used a video, as a previous meta-analysis concluded that presentation of film clips is the most effective technique for inducing both positive and negative moods (Westermann, Spies, Stahl, & Hesse, 1996). The video used for the sad MI, "Otto's Story," tells the story of a young child who dies of cancer (Haldenwang, 2012). This video was found to be especially effective inducing feelings of sadness in our pilot testing (as compared to several other videos that were considered), and this was also true for the participants in the present study, as more than 90% of them were successfully mood-induced (as described in the Results section). The neutral MI was always presented first in order to provide a common experience for participants so that a superior baseline measure of attention to the images could be obtained (presenting the sad MI before the neutral MI would also have risked a carryover effect if the sad mood persisted even for a few minutes given the brief interval between the presentation of the two videos). To help repair participants' moods, after the eye-tracking data was collected participants watched a video showing humorous animal scenes ("'America's Funniest Home Videos' Animal Clips," Associated Press, 2009). Participants watched the videos while alone in a quiet room. The video sound was played through headphones to help participants focus on the story of the sad MI video. (These videos are available from the authors upon request.)

Participants rated their mood using both scales at the following time points: (1) immediately before the neutral MI, (2) after the neutral MI and before the first eye-tracking data collection, (3) after the first eye-tracking data collection and before the sad MI, (4) after the sad MI and before the second eye-tracking data collection, (5) after the second eye-tracking data collection, (6) after completing the questionnaires and before the positive MI, and (7) after the positive MI. To be considered to have been successfully mood induced, participants had to endorse a 20-point decrease on the VAMS pre- versus post-sad MI, or a 2-point decrease in mood on the 11-point scale pre- versus post-sad MI (i.e., a 20% reduction in mood as measured by the VAMS or an 18% reduction as measured by the 11-point scale). This criterion ensured that only participants who experienced a decrease in mood were included in the analyses, similar to the procedure used in several other MI studies (e.g., Bisson & Sears, 2007; Newman & Sears, 2015; Singer & Dobson, 2007; Teasdale & Fogarty, 1979).

5.5. Stimuli for eye-tracking phases of the study

Each display included four images: a healthy food image, an unhealthy food image, and two non-food images. There were a total of 50 such displays presented; 25 were presented after the neutral MI and 25 were presented after the sad MI. Non-food images contained no food, and included a variety of everyday objects as well as generic scenes. Presenting the non-food images with the food images made the purpose of the study less obvious and provided stimuli other than food for participants to attend to. In addition, presenting unhealthy food images, healthy food images, and non-food images together allowed us to determine how these stimuli would be attended to when they competed for attention within the same display.

Prior to the study, a large set of food images were rated by undergraduate students to ensure agreement on the "healthy" and "unhealthy" categorization of the images. Two sets of images (the first set with 70 images and the second with 90 images) were rated by 34 and 39 students, respectively. For each image, participants were asked to rate its level of "healthiness" on a Likert scale from 1 to 7, with 1 equaling "very unhealthy" and 7 equaling "very healthy". Images were used in the study only if there was at least a 90% agreement that the food was "healthy" (rated as 6 or 7 on the Likert scale) or "unhealthy" (rated as 1 or 2 on the Likert scale). Healthy foods consisted primarily of low-caloric foods such as salad, fruits, and vegetables. Unhealthy foods included high-calorie items such as high fat meats, sweet foods, and snacks high in sodium.

5.6. Eye-tracking apparatus

Eye movements were recorded using an EyeLink 1000 eye-tracking system (SR Research Ltd., Ottawa, Ontario), which uses infrared video-based tracking technology. The system has a 1000 Hz sampling rate, a temporal resolution of 2 ms, and an average gaze error of less than 0.5 degrees of visual angle. Stimuli were shown on a 24-inch LCD monitor positioned approximately 60 cm away from the participant. Participants used a chin rest to minimize head movements while they viewed the images in order to maximize tracking accuracy.

5.7. Procedure for eye tracking

Following the neutral MI, the first eye-tracking data were collected. Before doing so, the eye-tracking system was calibrated for the participant, a procedure that required approximately 5 min. Data collection began once the calibration was successful. At the start of each trial, the participant fixated on a black dot in the center of the display for 2 s to ensure proper gaze measurement. The participant was presented with 25 sets of four images, with one image presented in each of the four corners of the display (top left, top right, bottom left, bottom right). As noted, each display consisted of one image of healthy food, one image of unhealthy food, and two images that contained no food items (the non-food images). Images were randomly assigned to the four corners of the display and across all of the trials healthy and unhealthy food images were equally likely to appear in each corner. The images were the same size and care was taken to match them on color, brightness, and complexity. Each display was presented for 8 s and eye gaze was tracked and recorded throughout this interval. The order in which the 25 trials were presented was randomized separately for each participant. Two practice trials were presented prior to the 25 data trials to familiarize participants with the procedure. Participants were instructed to look at the images freely, as if they were watching a slide show. Viewing all 25 sets of images required approximately 4 min. Following the sad MI, the participant was shown another 25 sets of four images, again consisting of one healthy food image, one unhealthy food image, and two non-food images. These two sets of 25 images were completely different and their presentation order was counterbalanced across participants.

6. Results

There were 35 participants in the control group and 31 participants in the food addiction group. Descriptive statistics for the two groups are listed in Table 1. The two groups did not differ significantly on their hunger or satiety measures (see Table 1). Not surprisingly, the two groups did differ in their BMIs, although the difference was not substantial. For the participants in the food addiction group, the mean BMI was in the overweight range, with a mean of 26.12 kg/m^2 (range of 17.23–42.91; SD = 6.93). For the participants in the control group the mean BMI (22.28 kg/m^2) was in the normal range (range of 17.71–34.33, SD = 3.66). BMI was controlled statistically in the preliminary analyses of the eye-tracking data described below and was not found to be an important moderator of any attention effects (and was therefore not used as a covariate in the final analyses).

6.1. Eating pathology

In addition to differing in their YFAS scores, the groups differed significantly on all of the other measures of eating pathology. Table 2 contains the group comparisons of EES and EDE-Q subscale scores. The food addiction group had higher scores on all three EES subscales: they had higher EES anger and frustration scores, $t(64) = 5.25$, $p < .001$, anxiety scores, $t(64) = 5.86$, $p < .001$, and depression scores, $t(64) = 5.57$, $p < .001$. The food addiction group also had higher scores on all four EDE-Q subscales: restraint, $t(64) = 7.12$, $p < .001$, eating concern, $t(52.74) = 12.56$, $p < .001$, shape concern, $t(61.78) = 9.02$, $p < .001$, and weight concern, $t(64) = 7.37$, $p < .001$. (Note that the degrees of freedom for some of these *t*-tests were adjusted to compensate for the lack of homogeneity of variance.) Cronbach's alphas were .93, for all three measures.

6.2. Mood induction efficacy and mood ratings

The mean VAMS and 11-point mood scale measures are shown in Table 3. There was a high correlation between the pre- and post-sad MI changes on the VAMS and the 11-point scale, $r = .70$, $p < .01$, indicating that both scales were measuring the same construct. As noted previously, a successful mood induction was defined as a decrease in the VAMS rating of at least 20 mm in the post-mood induction rating relative to the pre-mood induction rating or at least a 2 point decrease on the 11-point mood scale. Only participants successfully mood-induced were included the eye-tracking analyses, which ensured that any differences in attention to the images following the sad MI could be attributed to a decrease in mood. Overall, the sad MI was efficacious for 91.7% of participants, with 66 of the 72 participants included in the analyses based on these criteria. Mood induction efficacy did not differ significantly between the food addiction and control groups, $t(70) = 0.91$, $p = .36$. Specifically, of the 35 participants in the food addiction group, 31 were successfully mood-induced (88.6%), and of the 37 participants in the control group, 35 were successfully mood-induced (94.6%).

Additional analyses compared the magnitude of participants' mood shift following the sad MI to determine if the sad MI had a similar effect for the two groups. For the VAMS, the mean decrease post-sad MI for the control group (−33.6) was not significantly different than the mean decrease for the food addiction group (−41.8), $t(64) = 1.87$, $p = .07$. Similarly, for the 11-point mood scale, the mean decrease post-sad MI for the control group (−3.7) was not significantly different than the mean decrease for the food addiction group (−3.8), $t(64) = .21$, $p = .83$. A complementary technique for analyzing these changes uses a Group × Time (pre-sad MI, post-sad MI) mixed-model analysis of variance (ANOVA) to determine if there is an interaction, which would indicate that the sad MI was not equally effective for the two groups. The Group × Time interaction was not statistically significant for the VAMS measure, $F(1, 64) = 3.50$, $p = .07$, or for the 11-point mood measure ($F < 1$). These results indicate that the sad MI was equally effective for the two groups, and therefore any differences in attention between the groups cannot be attributed to a difference in the efficacy of the sad MI.

Table 2
Emotional eating scale (EES) and eating disorder examination questionnaire (EDE-Q) subscale scores.

	Food addiction group ($N = 31$)		Control group ($N = 35$)	
	M	*SD*	*M*	*SD*
EES – Anger/Frustration	32.48_a	8.57	22.08_b	7.51
EES - Anxiety	25.58_a	6.38	17.23_b	5.05
EES - Depression	19.41_a	4.05	13.82_b	4.03
EDE-Q - Restraint	2.92_a	1.13	1.05_b	.99
EDE-Q – Eating Concern	3.14_a	.95	$.57_b$	.66
EDE-Q – Shape Concern	4.54_a	.96	1.98_b	1.32
EDE-Q - Weight Concern	3.99_a	1.25	1.64_b	1.32

Note: Means with different subscripts differ at $p < .05$ in a t-test comparison.

Table 3
Visual Analogue Mood Scale (VAMS) and 11-point scale Ratings at all Time Points.

	Food addiction group ($N = 31$)		Control group ($N = 35$)	
	VAMS	Mood scale	VAMS	Mood scale
Time 1 – before neutral MI	68.9	2.0	66.4	1.7
Time 2 – after neutral MI	63.9	1.3	65.5	1.5
Time 3 – before sad MI	68.4	1.8	65.0	1.8
Time 4 – after sad MI	26.6	−2.0	31.4	−1.9
Time 5 – before questionnaires	49.2	0.03	49.7	−0.1
Time 6 – after questionnaires	44.6	−0.6	54.5	0.5
Time 7 – after positive MI	67.6	2.0	68.2	2.2

Note: MI = mood induction.

6.3. Eye-tracking data

The fixation data were processed using the EyeLink Data Viewer analysis software (SR Research) to filter for blinks, missing data, and other recording artifacts (using the default settings). To be included in the analyses, a fixation had to be at least 100 ms in duration; sequential, adjacent fixations less than 100 ms were merged and considered one fixation. Analyses of the remaining fixation data indicated that it was normally distributed. The fixation data for healthy and unhealthy images were averaged over the 25 trials presented after the neutral MI and averaged over the 25 trials presented after the sad MI. The data were analyzed using a 2 (Group: food addiction, control) × 2 (Mood Induction: neutral MI, sad MI) × 2 (Food Type: healthy food images, unhealthy food images) mixed-model ANOVA. The dependent variables were time of first fixation (the earliest point in the trial that a food image was fixated on, for any duration), first dwell time (the amount of time that a food image was fixated on immediately following the first fixation), and total fixation time (the total amount of time spent fixating on a food image during the 8-s trial). For these analyses, the critical statistical tests were the two-way interaction between Group and Food Type and the three-way interaction between Group, Mood Induction, and Food Type; to control the Type I error rate follow-up tests were carried out only for statistically significant interactions ($p < .05$). Statistically significant interactions were followed up with t-tests using an alpha of 5% to maximize statistical power.

Time of first fixation. For the time of first fixation, there was a main effect of Food Type, $F(1, 64) = 7.84$, $p < .01$, partial $\eta^2 = .11$. Averaging across Group and Mood Induction, unhealthy food images were fixated earlier in the presentations than healthy food images (1428 ms vs. 1542 ms, respectively). There was also a main effect of Group, $F(1, 64) = 7.06$, $p < .01$, partial $\eta^2 = .10$, with participants in the food addiction group fixating on food earlier in the presentations than participants in the control group (1365 ms vs.

1604 ms). This result suggests that food stimuli were more salient for participants in the food addiction group, as food stimuli attracted and engaged attention more effectively than it did for participants in the control group. The absence of an interaction between Group and Food Type ($F < 1$) indicated that this was true for healthy and unhealthy food images. No other effects were statistically significant (all *ps* > .10).

First dwell time. There was no main effect of Group ($F < 1$), as the overall first dwell times for the two groups were very similar (861 ms for the food addiction group and 886 ms for the control group). There was a significant Mood Induction × Food Type interaction, $F(1, 64) = 4.33$, $p = .04$, partial $\eta^2 = .06$, which reflected the fact that first dwell times for healthy food images were relatively unchanged after the sad MI (891 ms vs. 868 ms), whereas first dwell times for unhealthy images increased after the sad MI (826 ms vs. 910 ms). The absence of a three-way interaction, $F(1, 64) = 2.11$, $p = .15$, indicated that this pattern was similar for both the food addiction and control groups. There was also an interaction between Group and Food Type, $F(1, 64) = 12.90$, $p < .01$, partial $\eta^2 = .17$. Follow up comparisons using *t*-tests revealed that for the food addiction group, first dwell times for unhealthy food images were longer than first dwell times for healthy food images (921 ms vs. 801 ms), although this difference was not quite statistically significant, $t(30) = 1.92$, $p = .06$. In contrast, for the control group the opposite difference was observed, with shorter first dwell times for unhealthy food images than for healthy food images (815 ms vs. 957 ms), $t(34) = 3.48$, $p < .01$. An alternative way of interpreting this interaction is that the food addiction group had significantly shorter first dwell times for healthy food images than the control group (801 ms vs. 957 ms), $t(64) = 2.61$, $p = .01$, whereas there was no group difference for unhealthy images (921 ms vs. 815 ms), $t(64) = 1.40$, $p = .16$.

Total fixation time. Finally, for total fixation time (the total amount of time spent fixating on a food image during the 8-s trial), there was a main effect of Group, $F(1, 64) = 10.39$, $p < .01$, partial $\eta^2 = .14$, as participants in the food addiction group had longer total fixation times for food images than control participants (1802 ms vs. 1497 ms). There were also three significant interactions. The first was between Mood Induction and Food Type, $F(1, 64) = 9.48$, $p < .01$, partial $\eta^2 = .13$, and the second was between Group and Food Type, $F(1, 64) = 11.16$, $p < .01$, partial $\eta^2 = .15$. The Group × Food Type interaction reflected the fact that participants in the food addiction group had longer total fixation times for unhealthy images than participants in the control group (1940 ms vs. 1318 ms), whereas for healthy images the two groups did not differ (1663 ms vs. 1676 ms). These two-way interactions were qualified by a three-way interaction of Group, Mood Induction, and Food Type, $F(1, 64) = 4.19$, $p = .04$, partial $\eta^2 = .06$. The three-way interaction was followed up by examining the effect of the sad MI on attention to food images for the food addiction and control groups separately (Mood Induction × Food Type interaction contrasts). Results for the control participants are shown in Fig. 1 and results for the food addiction participants are shown in Fig. 2.

For the control group, the Mood Induction × Food Type interaction was not significant, $F(1, 34) = 2.19$, $p = .14$. As can be seen in Fig. 1, for control participants the sad MI had virtually no effect on attention to either healthy or unhealthy food images, as the total fixation times for both food types were very similar after the neutral MI and after the sad MI. Also note that healthy images were attended to significantly more than unhealthy images, $F(1, 34) = 20.75$, $p < .001$, partial $\eta^2 = .38$, which was the case before and after the sad MI. In contrast, for the food addiction participants the sad MI had a significant effect on their attention to both healthy and unhealthy food images, although the effect was different for each food type, which produced a Mood Induction × Food Type interaction, $F(1, 30) = 6.72$, $p = .01$, partial $\eta^2 = .18$ (see Fig. 2). For healthy food images, total fixation times decreased after the sad MI (1755 ms vs. 1571 ms), $t(30) = 2.29$, $p = .03$, whereas for unhealthy food images total fixation times increased after the sad MI (1769 ms vs. 2112 ms) = $t(30) = 2.20$, $p = .03$. Thus, the sad MI had the opposite effect on attention to healthy and unhealthy food images. Taken together, these results indicate that a sad MI affects attention to food only for individuals with food addiction.[1]

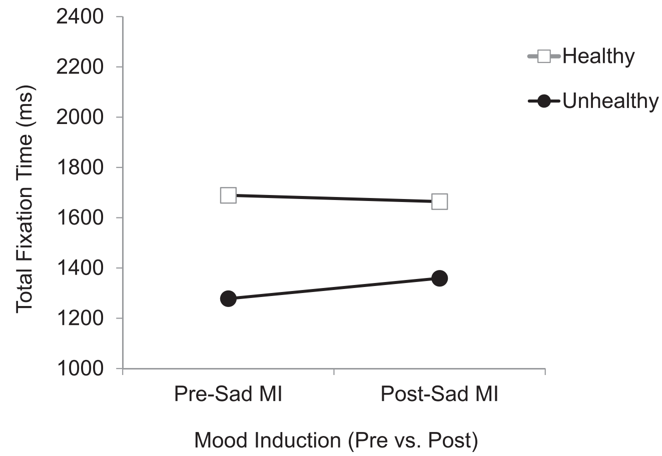

Fig. 1. Total fixation time for healthy and unhealthy food images before and after the sad mood induction (MI) for control group participants.

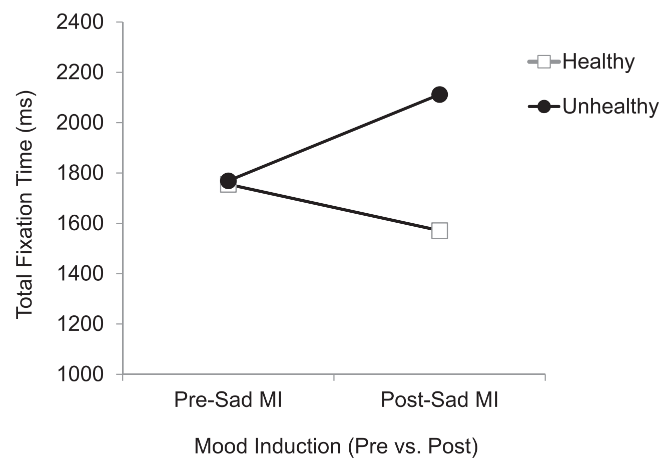

Fig. 2. Total fixation time for healthy and unhealthy food images before and after the sad mood induction (MI) for food addiction participants.

7. Discussion

Food addiction is a relatively new construct, and to date few studies have examined the cognitive processes associated with food addiction symptoms. Research examining attention to food in

[1] Controlling for BMI in the time of first fixation analyses using analysis of covariance (ANCOVA) did not produce changes in any of the group interactions for the eye-tracking data. For the first dwell time data, controlling for BMI did not change the Group × Food Type interaction, $F(1, 62) = 14.14$, $p < .001$, partial $\eta^2 = .19$. For the total fixation data, controlling for BMI did not change the Group × Food Type interaction, $F(1, 62) = 11.49$, $p < .01$, partial $\eta^2 = .16$, or the Group × Mood Induction × Food Type interaction, $F(1, 62) = 5.49$, $p = .02$, partial $\eta^2 = .08$. These results indicate that for this eye-tracking paradigm, BMI was not an important moderator of attention to food.

overweight and obese individuals (e.g., Bongers et al., 2015; Gearhardt, White et al., 2012) and individuals with binge eating (e.g., Popien et al., 2015; Schag et al., 2013) has observed heightened attention to food in these populations, which is relevant to food addiction given the overlap among these constructs. The purpose of the present study was to determine if food addiction is associated with attentional biases and if those biases are influenced by induced sadness.

Our first hypothesis, that participants in the food addiction group would attend to unhealthy food images more than participants in the control group, was partially supported. Consistent with this hypothesis, for total fixation times we found that participants in the food addiction group attended to food images significantly more than control participants, and additional analyses revealed that this difference was confined to the unhealthy food images, with no difference for the healthy food images. For first dwell times it was found that participants in the food addiction group had significantly shorter first dwell times for healthy food images than participants in the control group, whereas there was no group difference for unhealthy images. Taken together, these results suggest that although participants with food addiction attended to unhealthy food images more than control participants over the entire 8 s presentations there was no group difference when the unhealthy food images were first attended to. This finding suggests individuals with food addiction are distinguished by their sustained attention to unhealthy food and not their immediate attention to these stimuli. The analysis of the first dwell time data also revealed that participants with food addiction fixated on unhealthy food images longer than healthy food images when they were first attended to, whereas control participants fixated on healthy food images longer than unhealthy food images. For the control participants, this outcome may reflect increased salience of healthy foods due to less over-consumption of unhealthy foods, or it may reflect a coping/calorie control strategy such that healthy foods are purposely attended and unhealthy foods are avoided.

Recall that, in addition to their longer total fixation times for food images, participants in the food addiction group fixated on food images earlier during the 8-s presentations than control participants, suggesting attentional hyperviligance to food stimuli. Analyses of the time of first fixation data showed that this was true for both healthy and unhealthy food images, which suggests that the processes involved in the initial engagement to food stimuli may differ from those that contribute to the maintenance of attention over time. It may be that having a susceptibility to sustain attention to unhealthy foods may lead individuals with food addiction to increase consumption of such foods, although without measuring actual food intake in a study this interpretation cannot be tested.

Our second hypothesis, that participants in the food addiction group would increase their attention to unhealthy food images following the sad MI, was also partially supported based on the three eye-tracking variables we measured. For first fixation times we found that participants in the food addiction group increased their attention to unhealthy food images and decreased their attention to healthy food images after the sad MI. This finding suggests that unhealthy food images were used to repair mood for the food addiction participants following the sad MI (and therefore attracted more attention), which is consistent with previous research finding that food addiction is related to increased emotion dysregulation and impulsivity (Gearhardt et al., 2011). For participants in the control group, on the other hand, the sad MI had no effect on total fixation times for either healthy or unhealthy food images. Mood ratings indicated that the MI had comparable efficacy for both groups, which leads one to conclude that a sad mood did not significantly alter sustained attention to food in those without food addiction symptoms. This result likely reflects the fact that these individuals do not use food as a coping mechanism to deal with negative emotions. This interpretation is supported by control participants' lower scores on all subscales of the EES.

On the other hand, there was no evidence that the sad MI affected first dwell times or the time of first fixation to healthy or unhealthy food differently for participants in the food addiction and control groups. In fact, first dwell times for unhealthy food images increased for both groups following the sad MI. Taken together, the analyses of the eye-tracking variables indicate that for women with food addiction, a sad mood produces changes in sustained attention to food, and little or no changes in their immediate attention. While women with food addiction attended to food stimuli similarly to those without food addiction initially, the sad MI produced an increase in attention to unhealthy images and decrease in attention to healthy images when attention was measured over the entire 8 s presentations, which was not the case for the control participants. This outcome demonstrates one of the major advantages of using eye-gaze tracking to study attention in individuals with eating pathology—group differences in attention to food stimuli may not be pronounced when attention is measured only during the first few seconds after stimuli have been presented. In fact, if individuals with food addiction cope with a sad mood by attending to unhealthy food intentionally, then one would expect that this pattern of attending would be apparent only when attention was measured over relatively long intervals. The finding that participants in the control group did not sustain their attention to unhealthy food images following the sad MI suggests that they have a greater capacity to regulate their emotions and the impact these emotions have on attention to food. This supports Gearhardt and colleague's (2011) findings of greater levels of emotional dysregulation in those with food addiction.

As previously noted, there is evidence of attentional biases for food-related stimuli in populations with forms of eating pathology other than food addiction. For example, Popien et al. (2015) found that individuals with symptoms of binge eating exhibited increased attention to both high- and low-calorie food compared to those without binge eating, and Schag et al. (2013) found that participants with binge eating gazed longer at food images and had more difficulty inhibiting attention to these stimuli. Considering the association between binge eating and food addiction (Gearhardt, White et al., 2012; Imperatori et al., 2014), it is perhaps not surprising that individuals with food addiction would also exhibit attentional biases.

7.1. Limitations and directions for future research

There were several limitations of this study that should be considered when evaluating our findings. First, the generalizability of our results is unclear due to the lack of diversity in our sample. All of our participants were women, many of them Caucasian, and most were young undergraduate students, and so the extent to which our findings can be generalized to men, older individuals, and individuals of various ethnicities is an empirical question. Second, in addition to their difference on the YFAS measure of food addiction, the food addiction and control groups differed on other measures of eating pathology (the EES and the EDE-Q). The extent to which participants' attentional biases may have been influenced by their emotional eating (as measured by the EES) and their eating disorder psychopathology (as measured by the EDE-Q) is unclear, although the group differences on both of these measures was not large. Both YFAS symptom count and diagnosis have shown to be highly correlated with the EES in previous research, and group differences on both measures may account for variation in attention to food images (Gearhardt et al., 2009). Third, although attention to unhealthy food images was elevated in individuals with food addiction following the sad MI, actual food intake was not measured. Ideally, future research would assess food intake following a sad MI to determine if increased attention to food leads to increased food consumption.

Another question that could be addressed in future research is the impact of other mood states on attention to food in those with food addiction. One could consider the variations of negative emotion, from sadness, to frustration, to anger, and how these relate to individual differences in attention to food. The MI procedure we used was specifically designed to induce sadness. Based on scores from all three EES subscales, food addiction participants endorsed a greater likelihood of increasing food consumption when experiencing a depressed mood, which would suggest that our sad MI should have been especially effective. However, they also endorsed higher scores on the anger and frustration subscale of the EES, emotions that the sad MI procedure did not target. Additional research will be necessary to determine how other negative emotions such as anger and frustration may affect attention to food-related stimuli. One strategy would be to compare various forms of mood inductions related to emotional eating to determine whether or not attention to food differs among different emotional states.

Finally, given the limited research on cognition and food addiction, combining cognitive tasks with qualitative interviews would help to increase researchers' and clinicians' understanding of this condition and further evaluate its construct validity. These interviews would help to determine the conditions, emotional and otherwise, under which individuals with food addiction are motivated to eat, and may be a more externally-valid method of predicting problematic eating behaviors.

8. Conclusions

The purpose of this study was to examine attention to food images in women with and without food addiction symptoms, before and after a sad MI. The key finding was that participants with food addiction increased their attention to unhealthy food images and decreased their attention to healthy food images following the sad MI, whereas for control participants attention to both healthy and unhealthy food images was largely unaffected by the sad MI. These results have implications for furthering our understanding of the cognitive processes involved in food addiction. An important goal for future research will be to determine how cognitive processes, such as attention, contribute to the development and maintenance of food addiction, and how they can be addressed in prevention and treatment programs.

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