8-2018

Long-Term Focus of Attentional Biases

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Psychology

by

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August 2018
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This dissertation is approved for recommendation to the Graduate Council.

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Abstract

Prior research regarding attentional biases, or patterns of visual attention, have focused on attention over the initial second when exposed to pictoral food stimuli. This manuscript reviews the literature regarding attentional biases in overweight/obese individuals over this timeframe for the two previously defined components of attentional bias (attentional orientation and attentional maintenance). A new component is proposed, called “attentional re-engagement,” defined as the pattern of attentional shifts towards target stimulus types over longer periods of time. Overweight/Obese and Normal-weighted participants were recruited and engaged in an Extended Dot Probe task, wherein attentional orientation, maintenance, and re-engagement were assessed using the traditional dot-probe method, while long-term attentional re-engagement measures were also assessed via participant responses during long duration trials (15000ms). Participants also engaged in an eating task. The weight groups did not differ on attentional orientation, attentional maintenance, or any eating measure. Most participants experienced several attentional shifts in the long duration trials, but a small subset experienced very few attentional shifts. Within the majority of participants whose attention did shift in long duration trials, weight groups differed on the amount of attention directed to food images. This long-term attention to food images was also predictive of eating outcome in these individuals, suggesting that attentional re-engagement may be an unexplored component of attentional bias.

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Introduction

Consider the last time you entered a room that contained an open box of delicious donuts. Did you eat a donut? Now think back to where you were orienting your visual attention. Did you immediately attend to the box of donuts? Your visual attention was likely redirected elsewhere after a brief time looking at the treats, although it probably returned once or possibly several times throughout your time in the room. The direction of your visual attention during this time likely exhibited trends that manifest across a variety of foods; it may not always be donuts that catch your eye, but could also be pizza, candies, or other palatable foods. Given these tendencies to direct attention towards or away from food stimuli, it is important to gain a better understanding of (1) who generally experiences biased attention towards food, and (2) whether these attentional biases affect eating behavior.

Attentional bias, defined as visual attention directed toward or away from particular stimuli (Macleod, Mathews, & Tata, 1986), has been theorized to be incorporated in many behaviors beyond eating, including emotion regulation (Gross, 2015; Todd, Cunningham, Anderson, & Thompson, 2012), threat avoidance (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van lizendoorn, 2007), and substance use (Field & Cox, 2008). The role of attentional biases is subtle, and the above donut example has probably occurred to many of us whether we were aware of it or not. But why are some individuals prone to attentional biases towards palatable food stimuli in their environment while others are not? Incentive sensitization theory, which was initially proposed within the context of substance abuse, suggests that people become sensitized to stimuli that consistently predict future reward (Franken, 2003; Robinson & Berridge, 1993), which ultimately makes them pay more attention to those stimuli. As an example, someone who repeatedly consumes donuts will pay more attention to donuts compared to someone who avoids them, because the person who eats donuts associates seeing donuts with the rewarding qualities of actually consuming them. Because this person pays so much attention to donuts, they tend to also consume donuts more often than someone who avoids them entirely. The capacity for attentional biases to prompt eating behavior has been suggested in prior reviews (Field, Werthmann, Franken, Hofmann, Hogarth, & Roefs, 2016; Werthmann, Jansen, & Roefs, 2015). Further, consistent with the predictions of incentive sensitization theory, a recent review of weight loss failure in interventions for obesity has suggested that attentional bias to food stimuli contributes to dieting failure (Appelhans, French, Pagoto, & Sherwood, 2016).

Components of Attentional Bias

While attentional bias has been largely conceptualized as a single process, it may be useful to split attentional bias into different components based upon the time that the biased response occurs after exposure to a stimulus. See Figure 1 for a pictoral representation of these components over time. Prior to the creation of this manuscript, only the first two components of this figure have been empirically defined (attentional orientation and maintenance; Werthmann, et al., 2015). Of these components, attentional orientation has been examined the most thoroughly. While the range of time remains debated, attention orientation is believed to occur between 100 and 500ms after an individual has been exposed to a food cue (Castellanos et al., 2009; Loeber et al., 2012; Werthmann et al., 2015; Werthmann, Roefs, Nederkoorn, Mogg, Bradley, & Jansen, 2011). The other researched component has been dubbed attentional maintenance, and it involves maintained attention for longer time durations beyond attentional orientation. Attentional maintenance is thought to occur at >500ms after stimulus presentation (Mogg, Bradley, De Bono, & Painter, 1997, Werthmann et al., 2015). However, these two components of attentional bias only cover the initial second after exposure to a visual stimulus.

Thinking back to the example used at the beginning of this manuscript, your attentional shifts within the first second of observing available donuts may not have been the largest predictors of your eating behavior – instead, shifts in attention and re-engagement of attention towards the donuts may have also impacted your behavior. This measurement of attentional biases above one second are referred to herein as attentional re-engagement and are defined by the author as the tendency for some individuals to, over a relatively extended period of time, repeatedly shift attention away from and back to rewarding stimuli (in this case, food stimuli). To the author's understanding, attentional re-engagement has not previously been defined although some past research does hint towards its existence (e.g., Castellanos et al., 2009; Werthmann et al., 2011). To better understand all three components of attentional bias, it may be useful to integrate them with the neurological processes underlying visual attention.

Process of Visual Attention

Prior research suggests that there are four neurological processes of attention that function continuously: bottom-up salience filters, working memory, competitive selection, and top-down sensitivity control (Knudsen, 2007). Within this system, bottom-up salience filters make people quickly respond to salient stimuli in the environment (such as delicious food) and promote the inclusion of these salient stimuli in working memory for a few hundreds of milliseconds (Bisley & Goldberg, 2003). This process likely corresponds with measurements of attentional orientation, which occur in less than 500ms after exposure to a salient stimulus (Werthmann et al., 2015). Afterwards, top-down sensitivity control and competitive selection begin to "muddy the waters" of attentional bias measurements by shifting attention away from salient stimuli after initial orientation. Specifically, top-down sensitivity control increases or decreases sensitivity to certain stimuli and competitive selection then "chooses" what information to process in the environment based on weighted inputs from the other three processes (Knudsen, 2007). It is important to note that these processes all work in parallel and the inputs from each process are constantly updated moment-to-moment.

Conceptually, attentional maintenance requires not only bottom-up salience filters to promote attention directed toward salient stimuli, but also for top-down modulation to promote continued processing of those stimuli over extended time periods - basically, for someone to maintain attention to an object, that person needs to have initially oriented attention (due to bottom-up salience), but they also need to be motivated to continue attending the object (which influences top-down modulation). Considering that attentional maintenance requires both bottom-up and top-down processing towards that stimulus, what would happen if someone possessed a goal inconsistent with sustained attention (i.e., a goal to avoid high-calorie food; Hofmann, Schmeichel, & Baddeley, 2012)? This would force competitive selection to “choose” whether attention goes the direction pointed by either bottom-up salience filters or top-down modulation. This conflict between bottom-up and top-down inputs leads to attention potentially being shifted away or maintained during attentional maintenance. This process has been observed in the field of anxiety, wherein anxious individuals appear to experience difficulties disengaging attention from sources of threat (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). These individuals’ bottom-up salience filters may be weighted more heavily than the top-down modulation, which prevents them from disengaging attention as quickly as non-anxious participants. Importantly, this research suggests that the attentional system constantly redirects attention according to these weighted inputs which, over a long enough period of time, encompasses the proposed component of attentional re-engagement. For attentional re-engagement, the relative weights of bottom-up and top-down processes would affect the way that attention is later re-engaged towards or away from salient stimuli over longer lengths of time. With these processes in mind, the existing research regarding attentional orientation, maintenance, and re-engagement will be evaluated.

Attentional Biases to Food Stimuli

Nearly all people find palatable food to be rewarding, as has been shown by eye-tracking research (Nijs, Muris, Eauser, & Franken, 2010). However, several studies have investigated responses to food stimuli amongst groups of eating disordered (Aspen, Darcy, & Lock, 2013; Lee & Shafran, 2004) and obese/overweight participants (Nijs & Franken, 2012) and found that these groups attend to food-related stimuli to a greater degree than healthy controls. Past research has used a variety of stimuli types to investigate these phenomena, including food-related words as well as food images. Studies using word stimuli will not reviewed, as these are considered to be less valid (Aspen et al., 2013) and have been shown to elicit different attentional biases compared to pictoral stimuli (Freijy, Mullan, & Sharpe, 2014). Additionally, the below literature review will focus on attentional biases within populations of overweight and obese groups, as several recent studies have suggested that attentional biases towards food images differ between this group and normal-weighted individuals, and that such biases impact eating behavior (Field et al., 2016; Werthmann et al., 2015).

Attentional Bias Measurement. There have been several methods of measuring attentional bias used in the past literature. While the majority of past research has used the modified Stroop task, in which participants respond to the ink color of words rather than words themselves and reaction times to emotional words (such as food- or eating-related words) are compared to neutral words, has been criticized due to its lack of specificity, as differences in reaction times to different word types cannot be attributed exclusively to shifts in attention

(Aspen et al., 2013). Even if we could show that shifts in reaction time were due only to attention, we cannot be certain that the shifts occurred due to attentional shifts toward the word or because individuals simply avoided attending the word entirely (Werthmann et al., 2015). As such, no research will be reviewed from studies using the modified Stroop task.

Other measurements of attention are considered to be valid measures of attentional bias, including the pictoral dot-probe task, in which participants are presented a fixation cross in the center of a computer monitor, followed by the simultaneous presentation of two images for a timespan typically between 50 and 2000ms. After this time has elapsed, the images disappear and a response probe appears behind one of the two images that had been presented. In this task, participants are asked to respond to the probe as quickly as possible, response times averaged over many trials denote where attention is being deployed at the time of response probe presentation. See Figure 2 for an example of the pictoral dot-probe task. A further measure includes electroencephalography (EEG), wherein brain activity is measured in response to visual stimuli occurring 100, 200, and 300ms after image presentation (Wolz, Fagundo, Treasure, & Fernandez-Aranda, 2015). Brain activity at these timepoints is thought to correspond to early sensory processing and subsequent attentional orienting and selection processes. A final measure of attentional bias is eye tracking measurements, which assess momentary gaze direction, shifts, frequency, and length by measuring the physical direction of the eye. This remains the most valid measurement of visual attention available to researchers, as it requires the least amount of interpretation of the available methods (Nijs & Franken, 2012). Included in this review are empirical studies using dot-probe, EEG, and eye-tracking methods of attentional bias measurement.

Attentional Orientation. Two reviews have focused on attentional biases in overweight/obese groups to date (Nijs & Franken, 2012; Werthmann et al., 2015). Both reviews agreed that overweight/obese populations experience an overall attentional orientation towards high-calorie food stimuli beyond that displayed by normal-weighted controls. Indeed, several studies have shown attentional orientation towards food stimuli in overweight/obese populations using eye tracking methods (Castellanos et al., 2009; Werthmann et al., 2011) and the dot-probe task at 100ms (Nijs et al., 2010). Further research utilizing EEG methodologies have uncovered similar results that approached significance (Nijs et al., 2010).

Of note, several studies have found contradicting evidence. One study using a 50ms pictoral dot-probe task found no difference between overweight/obese and healthy control groups, leading the authors to suggest that measurements at 50ms occur too quickly for attentional orientation to occur (Loeber et al., 2012). Another study compared a group of underweight/normal body mass index (BMI) participants to overweight/obese on various measures of eye-tracking and found that the groups did not differ on overall amount of time attending food, but did find that the overweight/obese group oriented attention towards low calorie food more often than the underweight/normal group (Graham, Hoover, Ceballos, & Komogortsev, 2011). Importantly, attention was more often oriented towards high-calorie food images in both groups, but the underweight/normal group tended to avoid low-calorie images to a greater degree than overweight/obese. Problematically, the inclusion underweight participants may have altered the overall proportion of attentional orientations toward different food types, as lower BMI for normal-weighted participants has been shown to correspond to attentional orienting towards higher-calorie food (Nummenmaa, Hietanen, Calvo, & Hyönä, 2011).

Attentional Maintenance. Interestingly, the two published reviews (Nijs & Franken, 2012; Werthmann et al., 2015) differ regarding the conclusions on whether overweight/obese groups direct attention away from food stimuli during attentional maintenance (estimated to be ~500ms-1000ms after food exposure; Nijs & Franken, 2012). One review found that overweight/obese groups tend to avoid food stimuli during attentional maintenance (Nijs & Franken, 2012), while the other review concluded that the evidence was mixed whether overweight/obese individuals exhibited no bias or avoidance (Werthmann et al., 2015). While there are mixed results in this research, there is good evidence to suggest that overweight/obese individuals tend to quickly disengage attention during the attentional maintenance timeframe. In studies using a 500ms pictoral dot-probe, healthy controls were found to attend food images to a greater degree than overweight/obese participants, suggesting that the overweight/obese participants were avoiding the food stimuli after their initial orientation (Nijs et al., 2010). One study using eye-tracking to assess the duration of the initial orientation towards food images found that an overweight/obese group oriented attention toward food images more often than healthy controls, but spent less overall time attending that image (Werthmann et al., 2011); in other words, overweight/obese participants tended to quickly disengage attention from food images. Together, these studies suggest that overweight/obese groups tend to disengage attention during the attentional maintenance timeframe, indicating a motivated shifting of attention away from food stimuli.

Re-engagement. Per the time frame of attention described earlier (see Figure 1), attentional re-engagement should occur after 1 second of presentation. No studies have explicitly examined attentional re-engagement in the way that anxiety research has evaluated difficulties with attentional disengagement (Koster et al., 2006). Interestingly, attentional re-engagement may have been inadvertently previously explored in two prior studies (Castellanos et al., 2009; Werthmann et al., 2011). Both studies used a pictoral dot-probe task wherein images were presented for 2000ms and neither found any difference in attentional bias between groups of overweight/obese and normal-weighted participants. However, both studies found small-to-moderate effect sizes (*d* = 0.38, 0.48) in attentional bias between groups, but both studies lacked the statistical power to detect these effects. Importantly, previous eye-tracking research showed that the average time an overweight/obese or normal-weighted person spends viewing a palatable food image does not exceed 500ms (*SD* no larger than 250ms; Castellanos et al., 2009). Thus, any timeframe longer than ~1000ms for a stimulus presentation in a dot-probe task means that measurements are likely assessing the direction of attention that has already shifted away from the direction of initial orientation. Given that the majority of attentional orientations for overweight/obese participants are directed towards food stimuli (Castellanos et al., 2009; Werthmann et al., 2011), any assessed attention at 2000ms is likely measuring attention that has at least shifted once (e.g., attention oriented towards non-food image and shifted towards the food image) or twice (e.g., attention oriented towards food, shifted away, and then was later re-engaged). Essentially, these studies proposed that they were assessing attentional maintenance, but were likely assessing attentional re-engagement due to the long stimulus presentation time of 2000ms.

Summary. Overweight and obese populations appear to experience attentional orientation toward food stimuli. However, studies regarding attentional maintenance suggest that attention may shift away from food stimuli (e.g., Werthmann et al., 2011), although more research needs to be conducted to investigate attentional biases during this timeframe. Interestingly, overweight and obese populations also may re-engage attention towards food stimuli over timeframes of two seconds, which provides initial evidence that attentional shifts may be an important component of attentional biases that have been relatively unaddressed.

Attentional Bias Predicting Eating Behavior

Beyond knowing who is affected by attentional biases, it is important to also evaluate whether or not these biases are important predictors of future behavior. If attentional bias is one of the reasons that obesogenic environments tend to elicit eating behavior (e.g., Kirk, Penney, & McHugh, 2010), it may be a very useful target for future treatments for disordered eating behaviors and obesity.

Attentional biases have been theorized to be trait-level predictors of behavior (Field & Cox, 2008). Other theories state an individual's learning history prompts food-related stimuli to consistently elicit attentional biases, which then predict later eating behavior (e.g., Jansen, 1998). Unfortunately, few studies have examined whether attentional biases predict later eating behavior. In one study that incorporated eye tracking, EEG, and dot-probe measurements, it was found that no attentional bias measures correlated directly with amount of food eaten (Nijs et al., 2010). A second study found no correlations between amount of food eaten and eye gaze orientation, gaze duration, or responses to a 2000ms pictoral dot-probe task (Werthmann et al., 2011).

One recent study has shown a link between attentional bias and food consumption (Pollert & Veilleux, 2018). Individuals in this study either engaged in a task that required self-control exertion or a neutral task, followed by a 500ms pictoral dot-probe task, and then participated in a sham taste test to measure food consumption. It was found that attentional bias to food cues presented for 500ms predicted greater food consumption for only the individuals who had exerted self-control previously, while attentional bias did not predict eating behavior in the neutral condition.

While there exists little evidence from correlational studies to suggest that attentional biases to food stimuli are able to predict eating behavior, research from experimental studies have shown greater promise. Initially used in the anxiety domain (MacLeod, Rutherford, Campbell, Ebsworth, & Holker, 2002), Attentional Bias Modification (ABM) tasks have been used to modify attentional biases either towards or away from salient stimuli to assess the effect of attentional biases on later behavior. ABM tasks have been shown to alter attentional biases toward food (Renwick, Campbell, & Schmidt, 2013), wherein participants trained to attend food stimuli have been found to experience greater attentional bias toward food and to also have greater food intake compared to participants trained to avoid food stimuli (Kakoschke, Kemps, & Tiggemann, 2014; Kemps, Tiggemann, & Hollitt, 2014; Werthmann, Field, Roefs, Nederkoorn, & Jansen, 2014). Thus, ABM studies provide experimental evidence to support the notion that attentional biases may be predictive of later eating behavior, even though quasi-experimental and correlational studies have not been able to establish this link.

Summary. Correlational and experimental studies have displayed mixed results regarding the connection between attentional bias and food consumption, although it is notable that these studies have only assessed attentional orientation and maintenance. Few studies have examined the connection between attentional re-engagement and food consumption, and those that could be interpreted as having measured this connection did not have sufficient statistical power to evaluate these effects (Castellanos et al., 2009; Werthmann et al., 2011). More research is required to understand the connection between attentional biases and eating behavior overall, and research specifically focusing on attentional re-engagement may be critical in understanding how attentional bias relates to eating behavior.

Current Study

The current study is designed to answer several important questions regarding attentional biases and eating. Is attentional re-engagement an important aspect of attentional biases? If so, can we assess it using tasks similar to what has been used in past research assessing orientation and maintenance? Are there differences between normal-weighted and overweight/obese groups on attentional re-engagement? And finally, can attentional re-engagement predict eating behavior? This study will compare normal-weighted controls with obese/overweight participants to provide the first test of attentional re-engagement, to replicate past orientation and maintenance findings, and will also incorporate an eating task to evaluate whether any measured attentional bias components are able to predict eating behavior.

Several hypotheses are made with regards to replication of past findings using the dot-probe task. For attentional orientation, it is hypothesized that overweight/obese participants will experience more attentional bias towards food images compared to normal-weighted controls. Consistent with the research regarding attentional maintenance, it is hypothesized that overweight/obese participants will attend food images to a lesser degree than normal-weighted participants. Attentional re-engagement will also be replicated by using the dot-probe task used in prior studies (Castellanos et al., 2009, Werthmann et al., 2011), and it is hypothesized that overweight/obese participants will view food images to a greater degree than normal-weighted participants.

Attentional re-engagement will be assessed in two novel ways in this study, which should provide a more clear understanding of attentional re-engagement patterns. Participants will be exposed to an extended dot-probe task wherein they will view images for a long period of time and it is hypothesized that overweight/obese participants will experience a greater number of shifts in attention than normal-weighted participants. Given the hypothesized shifting of attention for overweight/obese participants, I also propose that there will be no difference in the overall amount of attention toward images of palatable food between groups over extended time periods, as greater attention shifts away from food stimuli will lead to greater re-engagement towards those stimuli in overweight/obese participants and lead to similar overall amounts of attention to food images compared to the normal-weighted group.

This study will incorporate an eating task to measure intake of food that corresponds to the types of images shown during the assessment of attentional biases. It is hypothesized that the overweight/obese group will consume a greater amount of food during the taste test task compared to the normal-weighted control group. Additionally, correlations between attentional bias measurements and food consumption will be assessed. Given the results of past research, it is hypothesized that attentional orientation and maintenance will not correlate with the amount of food eaten. Attentional re-engagement has not been adequately examined previously, and I hypothesize that the two novel measures of attention re-engagement will correlate with food intake in this study. Further, it is hypothesized that the relationship between attentional re-engagement and eating behavior will be moderated by weight group, such that re-engagement will predict greater eating for overweight/obese participants, while it will be unrelated for normal-weighted participants.

Method

Participants

Participants were drawn from an introductory psychology subject pool at a mid-southern university. Students completed an online screener, from which each potential participant's Body Mass Index (BMI) was calculated via self-reported height and weight. Exclusion criteria collected in the online screener included serious health problems that impact eating behavior (cancer, intestinal and digestive disorders, etc.), pregnancy, allergies to milk, potato, and chocolate, as well as vegetarianism and veganism due to being shown images and engaging in a taste task inconsistent with these dietary restrictions. Consistent with past research using these populations (e.g., Werthmann et al., 2011), participants were eligible for the normal-weighted control condition (Normal-weighted group) with a BMI between 18.5 and 25, or the overweight/obese condition (Ov/O group) with a BMI at or above 25. A total of 1821 participants completed the online screener. Of these, 911 were eligible to participate in the study. Eligible participants were invited to sign up for laboratory sessions via an online scheduling system, and in total 101 normal-weighted control subjects and 87 overweight/obese participants were recruited. Of these, 3 participants were excluded from all analyses due to computer problems, 1 due to not understanding the computerized tasks, and 1 due to misreporting chronic health problems affecting eating behavior on the screener, leaving 183 participants for analysis. Demographic information for the total sample as well as each group is provided in Table 1.

Measures

Individual Difference Measures.

Food Type Rankings. Participants responded to three questions asking them to rank order two types of food: sweet (e.g., cake, cookies, candies) and salty/savory (e.g., roasted peanuts, potato chips, pizza). The three questions asked: the food type that they crave more often, the food type they eat more often, and the food type that they "like" more. Responses on these questions were used to determine whether participants viewed sweet or salty/savory images on the Extended Dot-Probe Task (e.g., if a participant responded to two or more questions by selecting "sweet" food, they would only view images of sweet foods as the food images on the Extended Dot-Probe Task).

Sustained Attention. The Sustained Attention to Response Task (SART) is used as a measure of sustained attention and ability to inhibit responses, similar to a go no-go task (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). In this task numbers 0-9 are shown individually on a computer screen for 200ms, followed by a 900ms display of a red circle with a cross through the middle. Participants were asked to only respond to the number 3 by pressing a response button. Participants completed 150 randomized trials. To assess whether participants were able to sustain their attention to this task, they were asked the question after every 30 trials, "Are you paying attention to the task or is your mind/attention wandering?" (Jackson & Balota, 2012). The task lasted for approximately five minutes and participants responded to the sustained attention question five times. The proportion of times the participant responded that they were paying attention was converted to a percentage, as per prior research (Jackson & Balota, 2012), representing the percent of time that participants were able to pay attention to the task. Thus, participants responded on a measure of how well they were able to continue paying attention to a task that required sustained visual attention over a period of time with only intermittent behavioral responses, similar to the task used to assess attentional biases and especially attentional re-engagement.

State Measures

State Hunger. Consistent with prior research (Castellanos et al., 2009), state hunger was assessed through a ten point scale, from 1 "*Not At All Hungry*" to 10 "*Extremely Hungry*" (Herman, Fitzgerald, & Polivy, 2003).

State Craving. Participants completed a visual analogue scale (0 "*No current craving*" to 100 "*Extreme current craving*") for current state craving towards any food the participant desired.

Outcome Measures

Food Consumption. Food consumption was measured by asking participants to engage in a sham "taste test" task. Consistent with prior research (e.g., Pollert & Veilleux, 2018; Werthmann et al., 2011), participants were asked to eat from two available containers of highly palatable food. Each of these containers was filled with a food representing one of the two food types participants were asked to rate at the beginning of the study. Participants were given a container of salted potato chips representing salty/savory foods and a container of chocolate M&M candies representing sweet foods. All containers filled with food were weighed prior to food administration to be 125 grams with the container, thus providing participants with 85 grams of salted potato chips and 95 grams of chocolate M&M candies due to differing bowl sizes. Participants were given 8 minutes to complete their taste test and instructed to consume as much of the provided foods as they liked to facilitate their ratings. During this taste test task, participants also completed a sham rating form regarding the visual attractiveness, smell, and taste of each provided food. After the participant completed this task, the containers were weighed once again. The amount of food consumed was calculated by subtracting the post-administration weight of each container from its pre-administration weight.

Attentional Bias Measures

Extended Dot-Probe Task (EDP). The EDP was conducted on a wide-screen monitor. This task was essentially a modified pictoral dot-probe task changed to accommodate longer image presentation times with a method of measuring attentional deployment during these extended presentations. As with traditional dot-probe tasks, the participant was seated at the computer and each trial began with a blank white screen for 500ms. A fixation cross was then presented in the middle of the screen for 500ms. At the termination of the fixation cross, two images were presented, one on the left and one on the right side of the screen, each equidistant from the previous fixation cross. One of these images was of palatable food (either sweet foods or salty/savory foods, depending on the participant's highest ranked food type) and the other was of neutral images. Image selection is explained in more detail below. These images were presented randomly for one of the following timeframes: 300ms, 600ms, 2000ms, and 15000ms. After the allotted time for the image presentation elapsed, the images disappeared from the screen and were replaced with a probe that appeared in the space previously occupied by either the right or left image. The participants responded to this probe by pressing the left or right response button corresponding with the side of the screen on which the probe appeared. Response time difference scores for the 300ms, 600ms, and 2000ms trials were calculated as per the formulas used in prior research studies (Castellanos et al., 2009; MacLeod at al., 1986). The standard formula subtracts the mean reaction time on trials wherein the food image and the response probe appear on the same side of the display from the mean reaction time on trials wherein the food image and response probe appeared on opposite sides of the display. The formula used is:

M(Food x Non-Food Probe) - M(Food x Food Probe) = RTDifference

This formula allows the positive or negative sign of the resulting value to denote an individual's tendency to attend to the food stimuli (this value is referred to as a reaction time difference score). Positive values indicate attention toward food images while negative values indicate an attentional bias away from food images.

In this way, reaction time difference scores provide an understanding of which type of image, on average, participant groups are attending during their initial attentional orientation (300ms), to which image they are maintaining attention (600ms), and to which image they are re-engaging attention (2000ms). For longer time durations, however, knowing only where attention is directed at the termination of the images is not the most important piece of information – instead, knowing how often attention is shifting and in which direction these shifts occur may be more useful, particularly considering the rapidly increasing amount of attention variability between subjects as time increases.

Attentional Re-engagement. The procedure for the remaining 15000ms trials retains the traditional dot-probe methodology, but included the additional component of administering auditory notifications throughout the image display period. During the 15000ms trials, participants heard 7 auditory notifications. Each notification was 100ms in duration and sounded like a computerized "beep." There were three pre-programmed beep patterns in 15000ms trials, intended to help the participant feel that the beeps were "random." Each beep in these patterns was presented between 700ms to 1500ms after the prior beep. All participants were trained to respond to beeps by pressing the left or right response button, corresponding to the image that they were viewing at the time of the beep (e.g., if the participant was looking at the image on the left side of the screen when they heard the beep, they pressed the left response button). From these responses, participants provided information regarding how often their attention shifted between the left and right images as well as the overall number of notifications wherein they attended food images.

EDP Process. Participants completed 48 training trials (12 trials for each differently timed trial type), to acclimate to the required tasks. While prior research has typically used fewer practice trials (e.g., 10 practice trials in Nijs et al., 2010), one study conducted by the author using the traditional dot-probe task revealed that participants were unable to provide consistent reaction times for the first 45 trials (Pollert, Skinner, & Veilleux, manuscript in preparation). Essentially, it took 45 trials for participants to fully learn the task and provide consistent response times to probes after image termination. Thus, employing a greater number of training trials was intended to reduce artificial variability in participant responses due to learning the task.

Participants engaged in a total of 120 EDP trials after training. Consistent with past research, the first 60 trials were presented in a randomized order and these image pairs then had their orientations reversed and were again presented in a randomized order (e.g., the image pair was first presented with a slice of pizza on the left side of the screen and a stapler on the right – later, this same pair was presented with the slice of pizza on the right and the stapler on the left; Castellanos et al., 2009). Each trial timing (300ms, 600ms, 2000ms, 15000ms) was thus composed of 30 total trials. Each of these 15 unique trials was composed of 15 images of palatable food paired with 15 images of neutral items such as office supplies and common items in the home, as past research has utilized such stimuli (Hume, Howells, Rauch, Krof, & Lambert, 2015; Nijs et al., 2010).

Pictoral Stimuli Selection. All images used in this study were from the Food.pics database, which is offered freely online to researchers (Blechert, Meule, Busch, & Ohla, 2015). Food.pics provides a total of 568 food images and 315 non-food images, each of which is rated on a variety of scales, including valence, arousal, palatability, craving, recognizability, and visual complexity. All images were normed by a sample of 1988 individuals from German-speaking countries and North America (Blechert et al., 2015). For the purposes of this study, food images high in both palatability and craving as rated by the combined average of omnivorous males and females were selected for use.

Because there were two versions of the EDP used in this study (one with sweet food images and one with salty/savory food images), each version was created using images from the Food.pics database, which separates their images of palatable food into either a “sweet or “tasty” category. Images from their sweet category were used to populate the EDP with 60 sweet images and the images from the tasty category were used to populate the EDP with 60 salty/savory images.[1] Sixty images of home and office supplies from Food.pics were used as neutral pictoral stimuli (the same neutral stimuli were used in the sweet and the tasty versions of the EDP). Only images of American culturally normative items and foods were included in this study.

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[1] Salty/Savory Images (Palatability *M* = 63.88, *SD* = 4.58; Craving *M* = 42.42, *SD* = 5.01): 2, 3, 7, 10, 11, 12, 17, 22, 23, 27, 33, 37, 43, 45, 47, 54, 57, 58, 60, 61, 65, 68, 71, 72, 73, 76, 82, 85, 86, 87, 91, 98, 113, 141, 143, 144, 145, 188, 301, 304, 309, 311, 314, 315, 316, 319, 328, 329, 337, 378, 517, 519, 527, 545, 552, 556, 560, 562, 563, 566
Sweet Images (Palatability *M* = 68.68, *SD* = 4.90; Craving *M* = 47.86, *SD* = 6.23): 1, 4, 5, 6, 16, 18, 19, 25, 28, 36, 38, 42, 48, 49, 50, 67, 74, 83, 89, 90, 103, 111, 112, 115, 126, 140, 165, 168, 170, 192, 194, 202, 203, 209, 210, 211, 218, 221, 222, 234, 248, 280, 284, 287, 295, 296, 313, 355, 357, 379, 396, 397, 398, 452, 454, 465, 467, 478, 491, 492

Procedure

Participants who met inclusion requirements in an online screener for the normal-weighted or overweight/obese group were e-mailed and asked to participate in a research study. Participants were asked to fast for five hours prior to participating in the laboratory experiment to control for the effects of satiety, consistent with prior research incorporating food stimuli and eating tasks (e.g., Nijs et al., 2010; Overduin, Jansen, & Eilkes, 1997; Vohs & Heatherton, 2000; Werthmann et al., 2011). Upon entering the laboratory, participants were provided an informed consent form approved by the university Institutional Review Board. Participants then completed state measures, rank ordered food types (sweet or savory/salty), completed the SART to measure sustained attention ability, and then completed the Extended Dot-Probe (EDP) task to measure attentional biases using images of their highest ranked food type. Following the EDP, participants were moved to a different desk and engaged in a sham "taste test" to assess eating behavior. Participants were then debriefed and allowed to leave the laboratory.

Data Preparation

300, 600, 2000ms trials.

As per prior research (e.g., Amir, Weber, Beard, Bomyea, & Taylor, 2008; Pollert & Veilleux, 2018), trials with incorrect probe responses were identified, as were trials with extreme scores using stem and leaf plots, as response times too low indicate untruthful participant responding and response times too high indicate inattentive responding (trials with response times <176 or >770 were excluded). Some participants had particularly high amounts of incorrect and out-of-bounds trials. As per prior research (Pollert & Veilleux, 2018), the seven participants with >25% of these incorrect or out-of-bounds trials were excluded from analyses. All remaining incorrect or out-of-bounds trials were excluded from the analyses (254 incorrect, 1.5% of trials; 732 out-of-bounds, 4.4% of trials). Reaction time bias scores were then calculated (see above for formula). Importantly, because 7 participants were removed due to too many incorrect or out-of-bounds trials, a total of 176 participants were included in the data analyses for the 300/600/2000ms EDP trials. This is a different sample than will be included in the analyses for other aspects of this research study, such as covariate analyses, eating analyses, and long-term attention outcomes.

15000ms trials.

As there is no prior research in this area, data cleaning criteria had to be created based on prior research with shorter trial types and restrictions based on the research tools used. All 15000ms trials included 7 beep responses. No beep responses were excluded on the basis of reaction time, as reaction time measures were not used in the data analyses, but the number of missing beep responses were identified (1305 beeps, 3.3%). Any trials with more than two missing beeps were excluded (131 trials, 2.3%), as three or more missing beep responses was a significant missing amount of data for calculation of attentional shifts. Any trials missing the first beep response were removed from analysis (27 trials, 0.5%), as this data was difficult to justifiably impute. Two participants were responsible for the majority of trials missing first beeps or >2 beeps, as they did not respond to any beeps and were thus excluded. No other participants missed >25% of the beeps, but one participant did respond to all beeps by pressing the right response button and was thus excluded, leaving 180 participants for the 15000ms data analyses. All remaining missing beep responses were imputed to be the same response as the prior beep (e.g., if beep 4 was missing, it was imputed to be the same response as beep 3; 470 imputed beeps, 1.2%). Number of attentional switches and number of times participants paid attention to food objects were then computed.

Results

Covariates and Sample Characteristics

To account for baseline group differences on a variety of demographic and self-report variables, a series of independent samples *t*-tests and Chi-Squared analyses were conducted. See Table 1 for descriptive statistics and analysis outcomes. Chi-Squared analyses showed that Normal-weighted and Ov/O groups did not differ on type of images seen (sweet vs. salty/savory) or minority status (Caucasian vs. Non-Caucasian), but did differ on gender, with a greater proportion of females represented in the Normal-weighted group. Independent samples *t*-tests showed that weight groups did not differ significantly on baseline craving, time since last food consumption, trait self-control, or self-reported ADHD symptoms. Weight groups did differ on baseline hunger, age, gender, and difficulties with sustained attention.

Given these results, self-reported Gender was included as a covariate in all group comparison analyses. This covariate was included in dot-probe (300, 600, 2000ms trials) analyses and long-term attentional bias analyses. Sustained Attention was only included in long-term attentional bias analyses (15000ms), due to the increased importance of wandering attention on attention tasks that span such large amounts of time.

Importantly, self-reported hunger was not included as a covariate in the following analyses, as induction of hunger was intended by having participants fast prior to engaging in the study and average time since last food consumption did not differ between groups. Additionally, evidence suggests that such group-level differences in self-reported hunger may be due to misperceptions of underlying biological states or sociocultural pressures (particularly on the part of the Ov/O participants) rather than differences in actual drive to consume food (Herbert & Pollatos, 2014; Nijs & Franken, 2012; Stunkard, 1959). Further, baseline group differences in hunger between Ov/O and Normal-weighted participants have been noted in prior studies (e.g., Castellanos et al., 2009) and have not been controlled for in prior investigations of attentional bias using similar assessment paradigms. Age was also not included as a covariate in analyses, because while the difference between groups was significant, it was not in the author's opinion meaningful, being only one-half of a year mean difference and being primarily due to the lack of age diversity in the sample.

Data Exploration

All outcomes of interest were normally distributed. However, visual assessment of frequency graphs revealed the average number of attentional shifts on 15000ms trials was nearly bimodal, with a subset of both Normal-weighted and Ov/O groups reporting very few attentional shifts per trial (10 of the 99 Normal-weighted participants and 15 of the 84 Ov/O participants reported fewer than .5 attentional shifts per 15000ms trial, 13.6% of the entire sample herein referred to as the "No Shift Subset"; see Figure 3). This is noteworthy for several reasons: (1) the remaining scores not in the no shift subset form a normal distribution with an average of 2 attentional shifts per trial, and (2) the normal process of visual attention should promote several shifts in attention over the course of 15 seconds.

Further assessment of the no shift subset revealed that the no shift subset Ov/O participants overwhelmingly reported viewing food images during the 15000ms trials, while the no shift subset Normal-weighted participants primarily viewed non-food images; both of these patterns are distinctly different from attentional patterns of the remaining sample after the no shift subset was removed (further analyzed below). Further discrepancies between the weight groups within the no shift subset and remaining sample were examined, although statistical analyses were not performed due to power concerns stemming from small group sizes in the no shift subset, and the weight groups within these subsets evidence some possible differences on reaction time difference scores for the 600ms trials, self-reported craving, and the total amount of food eaten (see Table 2). Given these differences between the no shift subset and the remaining sample, it appears that these subset participants represent a qualitatively unique sample of individuals whose self-reported long-term attention differs from the remaining sample, and thus analyses using the long-term attentional bias measures were completed in two ways: (1) as initially proposed, using the entire sample of Ov/O and Normal-weighted participants (the "entire sample"), and (2) by analyzing the sample that remained after removing the no shift subset (the "remaining sample"). Weight group analyses were unable to be conducted within the no shift subset due to the small sample size and lack of power. First, all analyses using the entire sample will be conducted.

Group Differences in Entire Sample

All results are displayed in Table 3.

Dot-Probe Attention Outcomes.

Univariate ANOVAs including gender as a covariate showed that there was no significant difference in attentional bias between weight groups on the traditional dot-probe 300ms, 600ms, or 2000ms trials.

Long-term Attention Outcomes.

Univariate ANOVAs including gender and sustained attention covariates showed that there was no difference between the weight groups on the number of times they reported looking at food over the 15000ms trials, nor was there a significant difference on the number of attentional shifts over the 15000ms trials.

Eating Outcomes.

Univariate ANOVAs including gender as a covariate showed that there was no difference between the weight groups on the total amount of food eaten or the amount of highest ranked food eaten.

Correlations and Regressions.

Correlations between study variables are provided in Table 4 for both weight groups. For both weight groups, attentional bias measurements tended to correlate almost exclusively with other attentional bias measurements, with the exception of attentional maintenance towards food (600ms) correlating positively with the total amount of food eaten for normal-weighted participants. Further, the 15000ms attentional re-engagement measures were more strongly correlated with 2000ms reaction time difference scores for overweight/obese participants than the normal-weighted participants. Within these attentional re-engagement measures, it is noteworthy that the number of times attention was reported being on food images correlated positively with other measures of attentional bias, while the number of attentional shifts correlated negatively. Several linear regressions were conducted to evaluate whether attentional bias predicted eating behavior in the entire sample. As there are no groupwise comparisons in these analyses, gender was no longer entered as a covariate; however, BMI was added as a covariate to account for the biased weight group recruitment in all analyses and Sustained Attention was added as a covariate for only the long-term EDP outcomes (average # of food responses and average number of shifts in attention). Please see Tables 5 and 6 for specific information regarding each regression.

The first set of regression models assessed whether the standard dot-probe attentional bias measures predicted eating after controlling for BMI (see Table 5). Attentional orientation

(300ms), attentional maintenance (600ms), and attentional re-engagement (2000ms) were added simultaneously in each regression. The first regression model did not predict total amount of food eaten in grams, nor did any measure of attentional bias. The second regression model did not predict the amount of highest ranked food eaten in grams (sweet or salty/savory), nor did any measure of attentional bias.

The second set of regression models assessed whether the long-term EDP measures predicted eating behavior after controlling for BMI and Sustained Attention (see Table 6). The average number of times participants reported viewing food images and the average number of attentional shifts in 15000ms trials were added to the model simultaneously in each regression. The first set of regressions showed that the overall model did not predict total amount of food eaten in grams, nor did any individual predictor. The second set of regressions showed that the overall model did not predict the amount of highest ranked food eaten in grams, nor did any individual predictor.

To assess whether attentional re-engagement predicts eating behavior differently for each weight group, a moderation analysis was conducted via the PROCESS macro (Hayes, 2012). Sustained attention was included as a covariate. In the first analysis, the average number of times participants attended food images in 15000ms trials was added as an independent variable, weight group was the moderator, and total amount of food eaten in grams was the outcome. The overall model was not significant, $R^2 = .04$, $p = .11$, nor was there a significant interaction $t(173) = .01$, $p = .99$. In the second analysis, the average number of attentional shifts was included as the predictor. The overall model was again not significant $R^2 = .04$, $p = .12$, nor was there a significant interaction $t(173) = -1.03$, $p = .30$.

Analyses After Removing the No Shift Subset

See Table 7 for results from all between group analyses. Given the low sample size of the no attention shift subset, analyses were only conducted on the portion of the sample that remained after removing the no shift subset from the entire set of collected data (the "remaining sample").

Long-term Attention Outcomes.

Within the remaining sample, Ov/O and Normal-weighted groups were compared using univariate ANOVAs on the long-term attention outcomes from the 15000ms trials, including gender and sustained attention as covariates. There was found to be no difference in average number of attentional shifts between weight groups, but the weight groups did differ on average number of times attention was directed to food images, with the Ov/O group viewing food images less frequently than the Normal-weighted group.

Eating Outcomes.

Eating outcomes were assessed using univariate ANOVAs, controlling for gender differences between weight groups. There were no group differences in total amount eaten or amount of highest ranked food eaten.

Regressions.

Given the presence of the no attention shift subset in the previously conducted regression analyses, these analyses were re-run to better understand how long-term attention variables predict eating behavior in the remaining sample after controlling for BMI and sustained attention. Results can be found in Table 8. Amount of attention to food images and number of attention shifts were entered into regressions simultaneously. The overall models predicting both total and most highly ranked food eaten were significant, but the model fit increased by including the number of times participants paid attention to food images and the number of attentional shifts was not significant. However, the number of times participants reported viewing food images did significantly predict total amount of food eaten

The same moderation analyses conducted in the full sample were conducted with the remaining sample after the no shift subset was removed. Sustained attention was again included as a covariate. In the first analysis, the average number of times participants attended food images in 15000ms trials was added as an independent variable, weight group was the moderator, and total amount of food eaten in grams was the outcome. The overall model was not significant, $R^2 = .05$, $p = .13$, nor was there a significant interaction $t(148)= -.41$, $p = .68$. In the second analysis, the average number of attentional shifts was included as the predictor. The overall model was again not significant $R^2 = .04$, $p = .21$, nor was there a significant interaction $t(148)= -.24$, $p = .81$.

Discussion

This study was designed to assess the newly proposed construct of attentional re-engagement as well as replicate past findings for attentional orientation and maintenance. The assessment method for attentional re-engagement was novel to this study and provides an initial "jumping off point" from which future studies can conceptualize and evaluate this proposed construct. Further, the inclusion of an eating task provided a means to link attentional bias measures with actual eating behavior, while also considering weight group as a moderator of this proposed relationship.

Most hypotheses testing revealed nonsignificant group differences when analyzing the entire sample. In particular, there were no group differences on attentional orientation (300ms), attentional maintenance (600ms), the dot-probe assessment of attention re-engagement

(2000ms), or the amount of food eaten (total food amount, ranked food amount). While some past research has shown that Normal-weighted and Ov/O participants differ on attentional orientation and maintenance, the research is somewhat mixed (see Werthmann et al., 2015 for a review). Given the differing timeframes used in past studies, different assessments of attentional bias used (i.e., dot-probe reaction time, EEG, eye-tracking), and different measures using these tools (e.g., orientation frequency between groups, reaction time difference scores, P300 amplitudes), the null results from group comparisons in this study add more "grist for the mill" in understanding participants responses to probes at the 300ms and 600ms timepoints in attentional orientation and maintenance phase. For the dot-probe measure of attentional re-engagement at the 2000ms timepoint, the results in this study confirm past research findings (Castellanos et al., 2009, Werthmann et al., 2011), but do so with a larger sample size and adequate power to detect past effect sizes. However, the results of this study suggest that the effect size of reaction time difference scores at 2000ms may be much lower than what was found in prior research.

Surprisingly, the Normal-weighted and Ov/O groups did not differ on any measure of amount of food eaten. This finding does not follow the majority of the prior attentional bias studies that also measured eating outcomes (e.g., Nijs et al., 2010), although there are a minority of studies that have also shown no difference in eating outcomes between these groups (e.g., Werthmann et al., 2011), suggesting that while they are in the minority, the eating results of this study are not entirely unique. It is noteworthy that other research studies investigating amount of food eaten have also used a sham taste test, but for longer periods of time (e.g., Werthmann et al., 2011), had more food options available for consumption (e.g., Nijs et al., 2010), or provided slightly different instructions (e.g., "eat as much as you like"; Werthmann et al., 2011). Any of these methodological differences may have resulted in different food intake or group differences in laboratory settings. It is thus possible that the instructions and task design implemented in this study was not adequate to elicit an eating response as found in some other studies, or it may be that such group differences are often not found but simply not published.

No other study I am aware of has examined long-term attentional bias beyond two seconds after image presentation, and the traditional dot-probe method of assessing attention tends to break down at longer image presentation times due to the rapidly shifting nature of visual attention. Thus, measuring attentional re-engagement using the EDP took the form of examining the average number of times participants looked at food images and the average number of attentional shifts on 15000ms trials. Interestingly, analyses regarding the attentional re-engagement outcomes from 15000ms trials suggest that there are no group differences when comparing the entire sample weight groups to one another. Unfortunately, these long-term attention analyses using the entire sample, while important to conduct, do not adequately represent the data collected in this study.

While the majority of the sample reported regularly shifting attention over the course of 15000ms trials, a subset of participants (the no shift subset) reported few to no attentional shifts over this time period. The data gathered in this study is inadequate in understanding whether (1) this subset represents a unique population of individuals, (2) this subset exists due to participants lying on self-reported attention during the EDP task, or (3) the EDP measurement was not sensitive enough to detect some of the attentional shifts participants experienced. Exploration of the group differences between the no shift subset and the remaining sample indicate that there is likely a genuine difference between these groups, wherein the no shift subset is qualitatively different from the remaining sample. Unfortunately, only 13.6% of the sample was in the no shift subset, lending inadequate power to detect group differences that may exist between Normal-weighted and Ov/O participants within this subset of individuals, but their attention did trend in different directions, wherein Ov/O participants viewed food images to an extreme degree, while the no shift subset Normal-weighted participants avoided looking at food. This is particularly interesting considering that the Ov/O participants in the remaining sample (excluding the no shift subset) avoided food images, lending further credence to the idea that the no shift subset and the remaining sample may have discrepant baseline characteristics as measured by the EDP.

After removing the no shift subset from the collected data and only assessing the remaining sample, there was a group difference in the amount of attention directed towards food images in 15000ms trials, wherein the Ov/O group viewed food images less often than the Normal-weighted group. This finding indicates that Ov/O participants who were adequately measured by the EDP tended to avoid food stimuli compared to the Normal-weighted participants. This finding reinforces prior research on attentional maintenance that suggests Ov/O participants are intentionally avoidant of food cues (Nijs & Franken, 2012), although this research domain remains mixed (Werthmann et al., 2015). Because this effect was only found in long-term attentional bias measures, further investigation using long-term attentional bias measures could be fruitful not only in studies regarding food and eating, but also those involving substance and alcohol use, as these research domains have been closely related in theories of sensitization to environmental stimuli and its effect on attentional deployment (Field et al., 2016).

Regressions using the remaining sample showed that amount of attention to food images in 15000ms trials was able to predict total grams of food eaten. The average number of attentional shifts in 15000ms trials was a marginally significant predictor of this same eating outcome These results indicate that for participants whose attention was shown to vary on the EDP, long-term visual attention did predict eating behavior. Such a relationship between attentional bias measures and eating has not been established in the majority of prior correlational research studies, with few exceptions (Pollert & Veilleux, 2018), and these results may provide some initial insight into why so few past studies have not found this connection between attentional bias and eating. Simply put, we may have been searching in the wrong place – rather than investigating orientation and maintenance of attention in short-term attentional trials, it may be long-term attention that has a more significant impact on eating behavior when comparing already existing groups such as Ov/O and Normal-weighted populations.

While the reasoning behind short-term attentional bias predicting eating behavior involves learned or inherent sensitization to rewarding food cues which then drives attentional deployment (Field et al., 2016), long-term attention directed towards or away from food cues is likely driven by primarily cognitive mechanisms. In the Elaborated Intrusion Theory of Desire (Kavanagh, Andrade, & May, 2005), environmental cues "set off" a cognitive chain reaction, wherein the cues individuals are sensitized to (in this case, food cues; Robinson & Berridge, 1993) become the target of a person's visual attention in such a way that these cues intrude on normal cognitive processes and these individuals cannot help but elaborate on them. This elaboration can take on a few different forms, including cognitive elaboration (thinking about the cues), desire (wanting the cues), and further attentional bias (gathering more detail about the cues). So within the Elaborated Intrusion Theory, individuals are also motivated to direct more visual attention towards objects to which they are already sensitized, which, intriguingly, did not happen in the Ov/O group. Importantly, this model does not take into account the conflicting goals of many individuals who not only want to eat palatable food, but also want to control their weight (Schwartz & Brownell, 2004). Individuals who experience conflict between short-term desire to eat food and long-term dieting/weight control goals must, in the moment of exposure to the sensitized cue of food, choose where to direct their attention - towards the food object which is the target of their desire, or away from the food object which is in line with their long-term goal of weight control. This conflict is often found in chronic dieters, who experience difficulties controlling their weight due to these continuous conflicts between eating and weight control (Stroebe, Van Koningsbruggen, Papies, & Aarts, 2013). The long-term attentional bias away from food cues observed in Ov/O participants may be driven by this very conflict, and it's likely that the Ov/O group on average resolved this conflict by attempting to avoid palatable food cues and thus prevent further cognitive elaboration.

The process of cues eliciting desire closely reflects the research on the effect of palatable food cues on the reward system of obese women - when exposed to palatable food images, they exhibit an exaggerated response compared to normal-weighted controls in many brain regions involved in prompting desire, craving, and motivation (Stoeckel, Weller, Cook III, Twieg, Knowlton, & Cox, 2008; Volkow, Wang, & Baler, 2011). As it stands, efforts to avoid palatable food cues is a reasonable strategy to reduce or resolve conflict between short- and long-term goals by individuals who are susceptible to such cues. Of note, avoidance of food cues is reflected in many weightloss interventions, such as the Veteran Administration's MOVE! initiative (Kinsinger et al., 2009) and cognitive behavioral weight management (e.g., Cooper & Fairburn, 2001). In these interventions, rather than individuals facing regular and repeated conflicts elicited by viewing or smelling palatable food, many people employ a variety of methods of stimulus control (Stuart, 1967), such as not buying such foods in the first place or storing them in a place where they are less regularly viewed.

Future research using more sensitive measures such as eye-tracking will be important in confirming and replicating many aspects of this study. Of particular interest is determining whether the no shift subset is a unique population of individuals whose attention simply does not shift frequently, shifts too quickly to be adequately assessed by the EDP, or who are in some way lying about their attentional deployment when compared to the remaining sample. Unfortunately, the data collected in this study remains inadequate to address these issues, and likely can only be answered through the use of a direct measure of visual attention.

Surprisingly, there were very few bivariate correlations between attentional bias and other measures used in this study. Of note, attentional bias during the maintenance phase was the only bias measure to correlate with eating behavior, and even then only for the Normal-weighted group, which is surprising given the lack of weight group differences for both attentional maintenance as well as amount of food eaten. Most interestingly, the number of attentional shifts in 15000ms trials was negatively correlated only with long-term attention to food in Normal-weighted participants, while it was negatively correlated with attentional orientation (500ms), attentional re-engagement (2000ms), and long-term food attention (15000ms) in Ov/O participants. These correlations suggest that attentional shifts may indeed be used as a form of avoidance of food images, particularly in Overweight and Obese individuals who may be more sensitized to such cues and are intentionally trying to avoid directing their gaze toward palatable food (Robinson & Berridge, 1993).

Limitations

This study has several limitations that must be noted. Most particularly, this study used a self-report measure to assess long-term attention and shifts, which may have allowed participants to misrepresent their experiences during the EDP task. The assessment of long-term attention is interpretive rather than behavioral, and future research would benefit from the use of eye tracking for a behavioral measure of long-term attentional shifts and bias. Further, the sample for this study was college students, which is common in studies of attentional bias, but remains a limitation. Finally, while we controlled satiety by asking all participants to fast for a minimum of 5 hours, neither hunger nor satiety were controlled in other ways, such as through a feeding task prior to attentional bias measurement. Given the goals of this study, these methodological choices were made intentionally, but remain limitations that can be addressed in future research.

Strengths

There are several strengths to this study as well. As mentioned, this is the first study investigating truly long-term attentional bias and shifts. The creation and use of a new measurement task to investigate long-term attention is a particular strength, and this task can help future researchers to investigate long-term attention without eye tracking equipment. The use of semi-idiographic image sets to show participants is noteworthy, as it accounts for some important aspects of personal preference which could increase our ability to measure attention. Further, the use of standardized images allows these same images to be used in future studies by other researchers. Finally, the assessment of multiple aspects of attentional bias (orientation, maintenance, long-term attention, attention shifts) is a genuine strength, as it allows for a more full understanding of attentional deployment across time and incorporates different components of attention according to modern theories (Knudsen, 2007).

Conclusion

This is the first research to examine long-term attentional bias to food and the data revealed two possible groups of people - those whose attention shifts very little over long time periods, and those whose attention shifts several times. In those whose attention does shift, Normal-weighted participants viewed food images more often than Overweight/Obese participants. Further, in those whose attention does shift, the number of times they viewed food images predicted the amount of food they consumed. Both of these findings are unique to this study and provide a new type of attentional bias on which to base future research.

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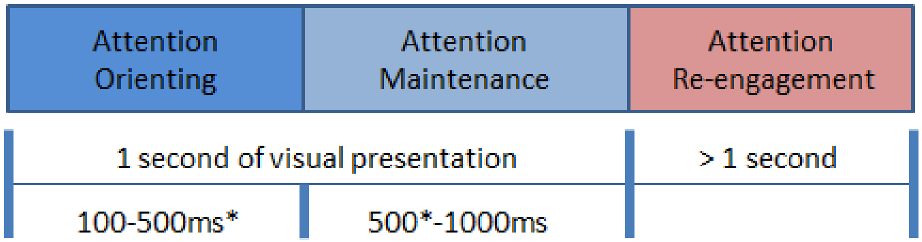
Appendix 1: Tables and Figures

Figure 1. Components of Attentional Bias and their timeframes



Note. These values are based upon those reviewed in Werthmann & Jansen, 2014.

*This value separating orientation and maintenance has been proposed to be as low as 200ms.

Figure 2. Example Dot-probe

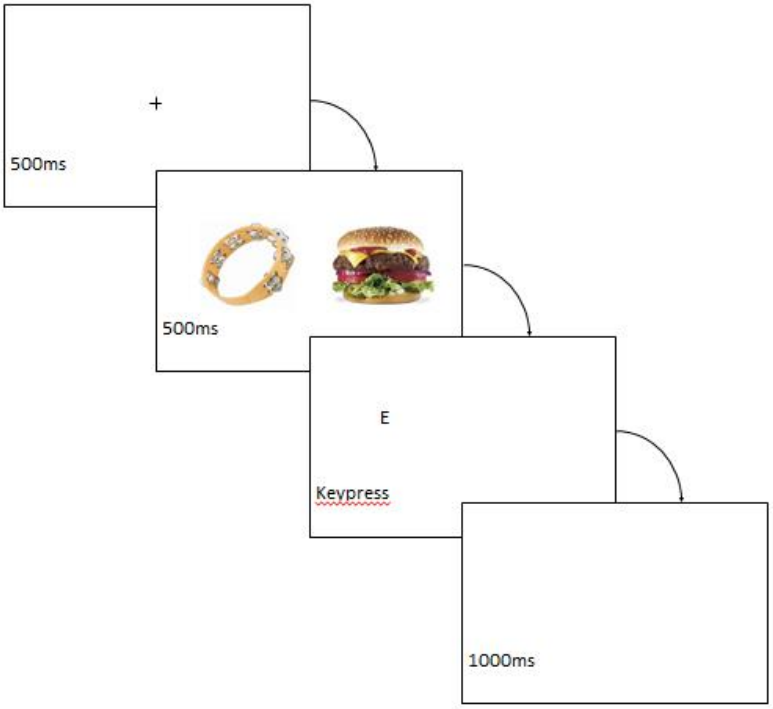
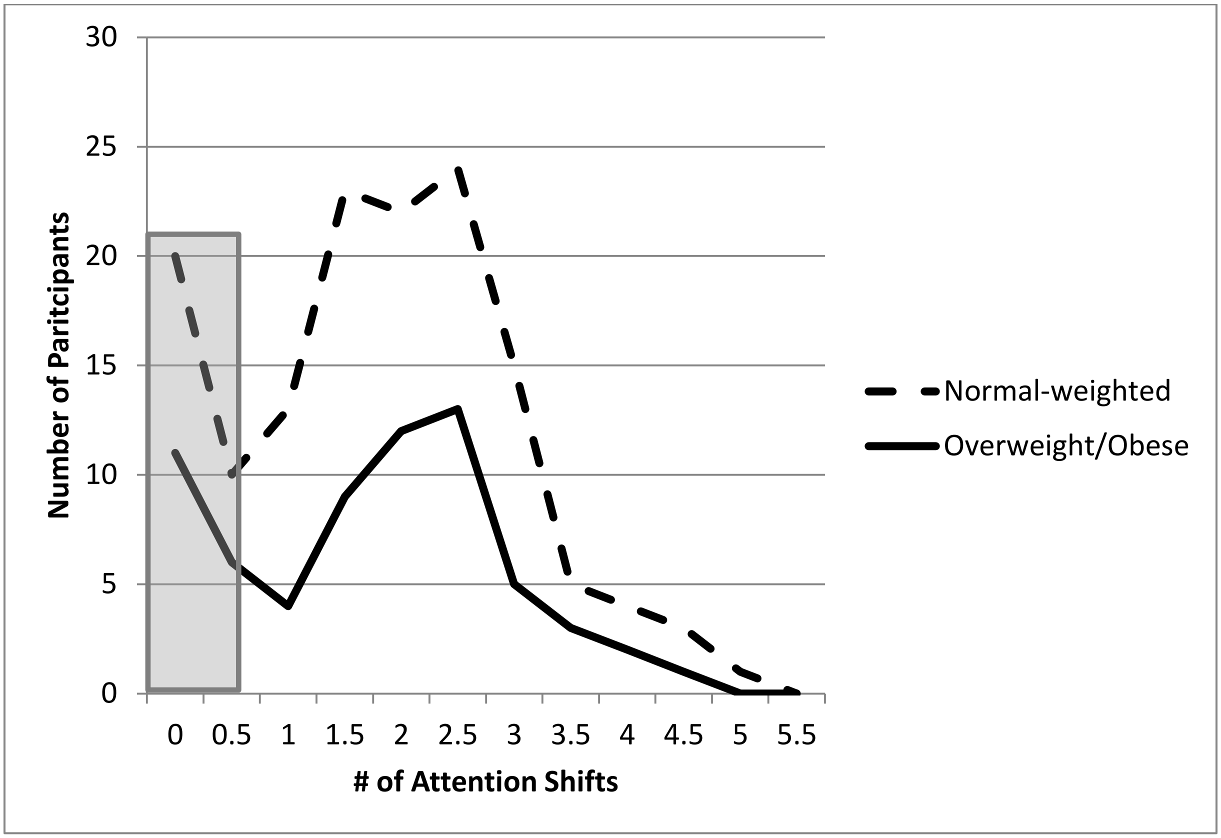


Figure 3. Average Number of Attention Shifts, Split by Weight Group



Note. The highlighted portion of the line graph denotes the No Shift Subset.

Table 1. *Demographic Information, Descriptive Statistics, and Covariate Analyses for Ov/O and Normal-Weighted Groups*

	Normal n=99 M (SD) or %	Overweight/Obese n=84 M (SD) or %	t-test or Chi-Square N=183
% Minority	8.08%	15.48%	χ^2=2.3, p=.13
% Female	68.69%	52.38%	χ^2=6.0, p=.01*
% Viewing Sweet Food Images	43.43%	30.95%	χ^2=3.01, p=.08+
Age	18.9 (.96)	19.4 (1.71)	t=-2.42, d=.36, p=.02*
BMI	22.22 (1.94)	28.92 (4.24)	t=-13.25, d=2.03, p<.001
Hunger	6.06 (1.65)	5.43 (1.95)	t=2.37, d=.35, p=.02*
Craving	5.53 (2.09)	4.94 (2.22)	t=1.83, d=.27, p=.07+
Hours Since Last Meal	11.05 (4.58)	11.72 (4.32)	t=-1.01, d=.15, p=.31
Sustained Attention	71.43 (31.33)	81.43 (25.18)	t=-2.39, d=.35, p=.02*

Note. Weight groups had unequal variances for BMI, Sustained Attention, and Age.

+ p<.1, * p<.05

Table 2. *Outcomes for the No Shift Subset and the Remaining Sample, Split by Weight Group*

	No Shift Subset		Remaining Sample	
	Normal-weighted *n*=10 M(SD)	Ov/O *n*=15 M(SD)	Normal-weighted *n*=88 M(SD)	Ov/O *n*=69 M(SD)
RTDiff 300ms	17.87(28.77)	21.63(36.36)	21.65(35.67)	13.18(31.75)
RTDiff 600ms	6.53(38.11)	30.06(42.04)	22.51(37.29)	15.36(36.08)
RTDiff 2000ms	16.49(35.39)	31.51(30.75)	10.40(31.57)	9.82(29.73)
Craving	5.70(1.16)	5.86(2.38)	5.45(2.15)	4.79(2.22)
Total Food Eaten	34.90(19.60)	49.60(41.91)	39.38(25.49)	42.13(31.45)
Ranked Food Eaten	19.20(14.11)	30.07(27.77)	20.95(15.28)	23.86(18.85)
# of Times Attention was on Food Images	4.60(1.87)	5.67(1.21)	4.57(.91)	4.24(.94)

Table 3. *Comparing Normal-weight and Obese/Overweight Participants from the Entire Sample on Study Outcomes*

		Normal M (SD)	Overweight/Obese M (SD)	Test Statistic
Attentional Bias	RTDiff 300	21.25 (34.90)	14.66 (32.52)	$F(2,170)=1.70$, $p=.19$, $\eta_p^2=.01$
	RTDiff 600	20.83 (37.50)	17.93 (37.33)	$F(2,170)=0.48$, $p=.49$, $\eta_p^2=.00$
	RTDiff 2000	11.04 (31.84)	13.62 (30.85)	$F(2,170)=0.18$, $p=.67$, $\eta_p^2=.00$
Attentional Re-engagement	# of Times Attention was on Food Image (out of 7)	4.57 (1.03)	4.50 (1.13)	$F(3,172)=0.22$, $p=.64$, $\eta_p^2=.00$
	# of Attention Switches (out of 6)	1.83 (1.00)	1.71 (.95)	$F(3,172)=0.32$, $p=.57$, $\eta_p^2=.00$
Eating Outcomes	Total Eaten (g)	39.16 (24.90)	43.46 (33.39)	$F(2,180)=0.64$, $p=.43$, $\eta_p^2=.00$
	Ranked Food Eaten (g)	20.89 (15.23)	24.96 (20.66)	$F(2,180)=1.44$, $p=.23$, $\eta_p^2=.01$

Note. Ranked Food Eaten is the food type most highly ranked by the participant via a questionnaire composed of three questions, either sweet or salty/savory foods, and this is the also the type of image that the participant saw during the EDP.

Table 4. *Correlation Table for Normal-Weighted Participants (Bottom) and Overweight/Obese Participants (Top) in the Entire Sample*

Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. RTDiff 300ms	===	**.35*** **	**.32** **	**.43*** **	**-.23***	0.21	-0.02	0	-0.07
2. RTDiff 600ms	.18	===	**.40*** **	**.39*** **	-0.17	0.2	-0.04	-0.04	-0.13
3. RTDiff 2000ms	**.20***	**.22***	===	**.53*** **	**-.44*** **	0.18	0.02	0.05	0.07
4. Food Attention 15000ms	**.28** **	.14	**.28** **	===	**-.59*** **	**.36*** **	0.08	0.07	0.04
5. Attention Shifts 15000ms	-.08	-.07	-.10	**-.37*** **	===	-0.16	-0.05	-0.08	-0.02
6. Craving	.12	.07	.04	.15	.06	===	0.08	0.09	-0.08
7. Total Food Eaten	.09	**.22***	.01	.12	.10	.19	===	**.93*** **	**-.22***
8. Ranked Food Eaten	.08	.16	-.01	.10	.07	.11	**.79*** **	===	-0.21
9. Sustained Attention	-.10	.0	.08	**-.21***	-.03	.01	-.12	-.04	===

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

Table 5. *Regression Analyses Using Dot-Probe Measures of Attentional Bias to Predict Eating in the Entire Sample*

	Overall Model	Model Change after Adding Attentional Bias	RTDiff 300	RTDiff 600	RTDiff 2000
Predicting Total Food Eaten (g)	R^2=.01, F(4,167)=.45, p=.78	ΔR^2=.01, ΔF(3,167)=.33, p=.80	B=.01, p=.94	B=.06, p=.35	B=-.01, p=.87
Predicting Ranked Food Eaten (g)	R^2=.01, F(4,167)=.37, p=.83	ΔR^2=.00, ΔF(3,167)=.09, p=.96	B=.01, p=.88	B=.02, p=.67	B=.00, p=.99

Note. + p<.1, * p<.05. BMI added as a covariate in all analyses. .

Table 6. *Regression Analyses Using Extended Dot-Probe Measures of Attentional Re-engagement to Predict Eating in the Entire Sample*

	Overall Model	Model Change after Adding Attentional Bias	Average Amount of Attention to Food Images (out of 7)	Average # of Attentional Shifts (out of 6)
Predicting Total Food Eaten (g)	R^2=.05, F(4,170)=2.05, p=.09	ΔR^2=.02, ΔF(2,170)=1.56, p=.21	B=4.18, p=.08+	B=2.83, p=.29
Predicting Ranked Food Eaten (g)	R^2=.03, F(4,170)=1.33, p=.26	ΔR^2=.01, ΔF(2,170)=1.04, p=.36	B=2.13, p=.15	B=.97, p=.56

Note. + p<.1, * p<.05. BMI and Sustained Attention added as covariates.

Table 7. *Weight Group Analyses for Remaining Sample after No Shift Subset Removed*

	Normal	Overweight/Obese	Test Statistic
Average Amount of Attention to Food Images (out of 7)	4.58 (.92)	4.24 (.94)	F(3,148)=4.15, p=.04, η_p^2=.03*
Average # of Attention Switches (out of 6)	1.99 (.87)	2.04 (.68)	F(3,148)=.13, p=.72, η_p^2=.00
Total Eaten	39.56 (25.58)	42.13 (31.45)	F(3,153)=.17, p=.68, η_p^2=.00
Ranked Food Eaten	21.01 (15.36)	23.86 (18.85)	F(3,153)=.58, p=.45, η_p^2=.00

Note. + p<.1, * p<.05. Gender added as a covariate in all analyses. Sustained Attention added as a covariate in Attentional Re-engagement analyses.

Table 8. *Attention Re-engagement Regression Analyses for Remaining Sample after No Shift Subset Removed*.

	Overall Model	Model Change after Adding Attentional Bias	Average Amount of Attention to Food Images (out of 7)	Average # of Attentional Shifts (out of 6)
Predicting Total Food Eaten (g)	R^2=.08, F(2,147)=3.07, p=.02*	ΔR^2=.03, ΔF(2,147)=2.65, p=.07+	B= 6.03, p=.04*	B= 6.49, p=.06+
Predicting Ranked Food Eaten (g)	R^2=.07, F(2,147)=2.70, p=.03*	ΔR^2=.02, ΔF(2,147)=1.70, p=.19	B= 3.30, p=.11	B= 2.81, p=.11

Note. + p<.1, * p<.05. BMI and Sustained Attention from the SART added as covariates.

Appendix 2: IRB Approval Memo

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

December 1, 2016

MEMORANDUM

TO:	Garrett Pollert Kaitlyn Chamberlain Danielle Baker Morgan Hill Jennifer Veilleux
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	16-11-243
Protocol Title:	*Long-term Focus of Attention*
Review Type:	☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 11/30/2016 Expiration Date: 11/29/2017

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (https://vpred.uark.edu/units/rscp/index.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 180 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.