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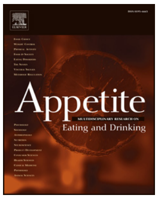

Influence of hunger on attentional engagement with and disengagement from pictorial food cues in women with a healthy weight

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ABSTRACT

Because of inconsistencies in the field of attentional bias to food cues in eating behavior, this study aimed to re-examine the assumption that hungry healthy weight individuals have an attentional bias to food cues, but satiated healthy weight individuals do not. Since attentional engagement and attentional disengagement have been proposed to play a distinct role in behavior, we used a performance measure that is specifically designed to differentiate between these two attentional processes. Participants were healthy weight women who normally eat breakfast. In the satiated condition ($n = 54$), participants were instructed to have breakfast just before coming to the lab. In the fasted condition ($n = 50$), participants fasted on average 14 h before coming into the lab. Satiated women showed no stronger attentional engagement or attentional disengagement bias to food cues than to neutral cues. Fasted women did show stronger attentional engagement to food cues than to neutral cues that were shown briefly (100 ms). They showed no bias in attentional engagement to food cues that were shown longer (500 ms) or in attentional disengagement from food cues. These findings are in line with the assumption that healthy weight individuals show an attentional bias to food cues when food stimuli are motivationally salient. Furthermore, the findings point to the importance of differentiating between attentional engagement and attentional disengagement.

1. Introduction

Overweight and obesity are major problems in today's society. Currently, 39% of adults are overweight and 13% obese (World Health Organisation, 2018). The World Health Organization (WHO) states that overweight and obesity are preventable, and recommends that people restrict their caloric intake, increase their fruit and vegetable consumption, and engage in frequent physical activity (World Health Organisation, 2018). However, people have a hard time adhering to self-set rules on food restriction (Knäuper, Cheema, Rabiau, & Borten, 2005), and only about 20% of overweight individuals seem to be successful in achieving long term weight loss (Wing & Phelan, 2005). It thus seems important to enhance our understanding of factors that control food intake (e.g., Loeber, Grosshans, Herpertz, Kiefer, & Herpertz, 2013). One characteristic that has been of interest in this regard is attentional bias (AB) to food cues (e.g., Castellanos et al., 2009). As a first step in understanding how AB to food cues might play a role in obesity, it seems important to understand the role of AB to food cues in healthy eating behavior.

Individuals' attention has been proposed to be biased towards stimuli in the environment that have a positive value (e.g., rewarding stimuli), and attention to rewarding stimuli is associated with increased response activation and approach behavior to these stimuli (Anderson, 2017; Higgs et al., 2017; Pool, Brosch, Delplanque, & Sander, 2016). Since food is thought to have a high intrinsic reward value (Robinson & Berridge, 2001), an attentional bias to food stimuli might therefore contribute to individuals' food intake (cf. Berridge, 2009; Franken, 2003). Moreover, it has been suggested that heightened AB to food cues lowers the threshold for overeating and may thus set individuals at risk for the development of overweight and obesity (Berridge, Ho, Richard, & Difeliceantonio, 2010; Polivy, Herman, & Coelho, 2008).

However, results regarding differences between obese and healthy-weight individuals in their attention to food cues have been inconsistent (Field, Werthmann, & Franken, 2016). Some studies showed stronger AB for food in obese compared to healthy weight individuals (Kemps, Tiggemann, & Hollitt, 2014; Nijs, Muris, Euser, & Franken, 2010), whereas several others found no evidence for a difference (Loeber et al., 2012; Werthmann et al., 2011). On top of that, attempts to modify AB for food in obese or unsuccessful dieters have been largely ineffective in influencing eating behavior (Boutelle, Kuckertz, Carlson, & Amir, 2014; Jonker, Heitmann, et al., 2019; Stice, Lawrence, Kemps, & Veling, 2016; Verbeken et al., 2018).

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The inconsistencies in the field have driven us to revisit the studies that lie at the foundation of the work on the role of attentional bias in obesity. These earlier studies integrated the influence of hunger on attentional bias in the comparison between healthy weight and obese individuals. That is, these studies examined whether attentional bias to food might differ between healthy weight and obese individuals when taking the potential influence of hunger into account. For healthy weight individuals the reward value of food is higher when individuals are deprived of food than when they are satiated (Higgs et al., 2017), and the value might even approach neutral when satiated (Berridge et al., 2010; Small, Zatorre, Dagher, Evans, & Jones-Gotman, 2001). If indeed the attentional bias to food cues is related to the reward value of food, the bias should be strong following deprivation and relatively weak or even absent when satiated. In line with this assumption, one important previous study found that healthy weight individuals only showed an attentional bias to food cues when they were deprived of food for more than 8 h, whereas obese individuals still showed an attentional bias to food when they were satiated (Castellanos et al., 2009). However, two later studies using fasting periods of 10–12 h (Stamataki, Elliott, McKie, & McLaughlin, 2019) or more than 17 h (Nijs et al., 2010) did not show this same interaction between weight status and hunger condition.

Going even a step further back, there is also no consistent empirical evidence for the notion that food deprived healthy weight individuals would, whereas satiated healthy weight individuals would not, have an attentional bias for food cues. Healthy weight individuals with high self-reported hunger have been found to show a greater attentional bias to food cues than individuals low in self-reported hunger as indexed by differential reaction times within the context of a 500 ms visual probe task (VPT). However, a similar pattern was absent in the context of a 14 ms VPT (Mogg, Bradley, Hyare, & Lee, 1998). In addition, a more recent study could not replicate this earlier finding using a 50 ms or 500 ms VPT (Loeber et al., 2013). Furthermore, studies that experimentally manipulated hunger status provided only limited and somewhat inconsistent evidence for the influence of hunger on attentional bias. In one study, healthy weight individuals who were food deprived for more than 8 h showed a higher attentional bias to food cues than satiated healthy weight individuals, but only as measured with eye-tracking and not on reaction times in the context of a 2000 ms VPT (Castellanos et al., 2009). In contrast, in another study healthy weight individuals who were food deprived for 10–12 h showed a higher attentional bias to food cues than satiated healthy weight individuals, but only as measured with the reaction time measure of a 100 ms VPT, and not on a 500 ms VPT, or on an eye-tracking measure (Nijs et al., 2010). Thus, the available findings provide no consistent pattern and no robust basis for drawing a final conclusion with regard to the question whether hunger plays a role in healthy weight individuals' attention for food. Hence, this study was designed to arrive at a more final conclusion regarding this role. In order to do so we made several important changes compared to the designs of previous studies.

First, a serious weakness of the previous studies is that they included a limited number of participants. For example, the study of Mogg et al. (1998) only included 16 participants in the fasting and 16 participants in the non-fasting group, and the study of Castellanos et al. (2009) relied on only 18 healthy weight individuals who participated once in a fasted and once in a satiated state. As a consequence these studies had very limited power (< 30%) which might have led to an under- or overestimation of the true effect and therefore also low reproducibility (Button et al., 2013). In the current study, our sample size will reach sufficient power (i.e., 95% to find a medium effect size) to examine the influence of hunger on attention to food cues.

Second, the statistical approach of previous studies did not allow to directly examine whether there is an AB in food deprived individuals and whether such bias is absent in satiated individuals. That is, such a question cannot be answered by the commonly used frequentist analyses, since these analyses can only find evidence to reject null-hypotheses and not to accept the null-hypothesis. In line with the boundaries of the analyses following the frequentist approach, previous studies only examined differences between groups. A limitation of this approach is that finding a group difference does not necessarily mean that the AB is absent in one group, and present in the other. Therefore, Bayesian analyses will be included in the current study allowing to examine the evidence in favor of the null-hypothesis.

Third, previous studies were unable to examine the potentially distinct role of attentional engagement and disengagement in eating behavior. Attentional engagement (i.e., automatic orientation towards food cues) and disengagement (i.e., redirection of attention away from food cues) have been proposed to play a distinct role in behavior (Mogg & Bradley, 2016; Posner, Inhoff, & Friedrich, 1987). Furthermore, these two processes might be differentially related to eating behavior. For example, attentional engagement might be specifically implicated in healthy eating behavior (Jonker, Glashouwer, Hoekzema, Ostafin, & De Jong, 2019), whereas attentional disengagement might be specifically implicated in compromising dieting success (Franken, 2003; Jonker, Heitmann, et al., 2019). However, previous studies on the role of food deprivation on attention to food cues used AB tasks unable to differentiate between attentional engagement and attentional disengagement (Grafton & MacLeod, 2014). If these processes are differentially influenced by hunger, using such combined measures might have unwanted effects on the results. For example, if engagement would increase as a result of hunger and disengagement would decrease, the results would show no change in attentional bias as measured as the combination of these two processes. Therefore, in this study, AB to food cues will be assessed with a performance measure that differentiates between attentional engagement and attentional disengagement (Grafton & MacLeod, 2014; Jonker, Glashouwer, et al., 2019). The task will include trials in which cues are shown for 100 ms and 500 ms providing the opportunity to examine whether it is a faster (i.e., more automatic) or slower (i.e., controlled) bias in attention that is relevant.

In summary, the following hypotheses were tested in the current experimental study examined: (1) satiated healthy weight individuals do not show more attention to food cues than to neutral cues, (2) fasted healthy weight individuals do show more attention to food cues than to neutral cues, and (3) fasted healthy weight individuals show stronger ABto food cues than satiated healthy weight individuals. As a subsidiary issue, we will explore whether hunger has a similar or differential impact on food-related attentional engagement and attentional disengagement.

2. Method

2.1. Participants

Women with a healthy weight (i.e., BMI between 18.5 and 25) who normally eat breakfast were eligible for participation in this study. To obtain a power of 95% to find a difference of medium effect size on the one sample *t*-tests while controlling for multiple testing ($\alpha = .05/4 = .0125$) because of our four attentional bias measures, a sample size of 63 per group is needed. Only women were included because gender might play a key role in the relation between attention to food cues and eating behavior (Hummel, Ehret, Zerweck, Winter, & Stroebele-Benschop, 2018), and dieting behavior is more common in women (De Ridder, Adriaanse, Evers, & Verhoeven, 2014; Wardle, Haase, & Steptoe, 2006). Participants were recruited via flyers specifically stating these inclusion criteria which were spread via social media and placed at University faculties. Additionally, first year psychology students were recruited via the online platform for psychology research. If interested, women were asked to complete a screening questionnaire. From the self-reported height and weight on this screening questionnaire we calculated BMI (i.e., self-reported BMI). In total 163 individuals completed the screening, of which 1 was male, and of 8 individuals their self-reported BMI was not within the healthy range. Of the remaining

154 women who were eligible, 129 women aged 18–35 (*Mean* = 22.43, *SD* = 3.16) with a self-reported BMI within the healthy weight ranges (*Mean* = 21.43, *SD* = 1.82) participated in the study. Of these 129 women, 14 were recruited via the university's online platform and 115 via flyers.

2.2. Measures

2.2.1. Hunger scale

The item “How long has it been since you last ate?” from the Hunger Scale (Grand, 1968) was used to examine participants' compliance to the study instructions. Scores reflect the number of hours that have passed since the participants last ate, rounded off to quarters of an hour. Furthermore, the item “How hungry do you feel right now” which was answered on a 7-point scale from *not hungry at all* (1) to *extremely hungry* (7), was used to assess whether food deprivation also led to higher subjective hunger ratings.

2.2.2. Eating disorder symptoms

For descriptive purposes eating disorder symptoms were assessed with the Eating Disorder Examination Questionnaire (EDE-Q; Fairburn & Beglin, 2008). Questions are answered on a scale from 0 to 6. An average score of the 22 items was used as general index of eating disorder pathology (cf., Aardoom, Dingemans, Slof Op't Landt, & Van Furth, 2012). Internal consistency of this global EDE-Q score was excellent in both the non-fasting and fasting condition (Cronbach's alpha = .94 and .93 respectively).

2.2.3. Attention to food

Attentional engagement with food cues and difficulty to disengage from food cues were assessed with The Attentional Response to Distal vs. Proximal Emotional Information (ARDPEI) task that was originally designed by Grafton and MacLeod (Grafton & MacLeod, 2014; Jonker, Glashouwer, et al., 2019). The ARDPEI was programmed in E-prime 2.0 (Schneider, Eschman, & Zuccolotto, 2002), and performed on a desktop computer with a 27 inch screen.

Task procedure. See Fig. 1 for a screen by screen overview of an ARPDEI trial. Each trial started with a white square left, and a white square right from the middle of the screen, against a middle gray background. Participants were instructed to focus their attention to a red outline that appeared in one of the two white squares. This red outline appeared with equal probability in the left or the right white square. After 1000 ms a red line (i.e., the anchor) appeared within this red outline. This anchor was either a horizontal or vertical line, and it appeared for 150 ms. Hereafter, two images, a representational image which is either a food or neutral image (i.e., Image Category) and an abstract art image, replaced the two white squares. The images appeared with equal probability in the left or the right square, and thus appeared distal or proximal to the anchor (Image Position). Following Grafton and MacLeod (2014), images were shown for 100 or 500 ms (Image Time) to examine differences between long and short exposure duration. Following the images, another red line (the probe), appeared on the left or right side of the screen. This red line was, with equal probability, a horizontal or vertical line. After the probe appeared on the screen, participants had to identify as quickly as possible whether the anchor and the probe had the same orientation (i.e., both horizontal or vertical) or a different orientation (i.e., one horizontal and one vertical) by pressing the corresponding button on the USB response box (Probe position). The task thus contains 16 different types of trials (Image Category (2) x Image Position (2) x Image Time (2) x Probe Position (2)).

The original task consisted of 128 trials which were presented in randomized order (Grafton & MacLeod, 2014; Jonker, Glashouwer, et al., 2019). This means that there are 8 trials per trial type (e.g., a 100 ms food trial where the food image appears distal to the anchor, and the probe has a different position than the food image). In the current study, participants performed this short version of the task twice, directly following each other, to provide a more accurate reflection of the true bias.

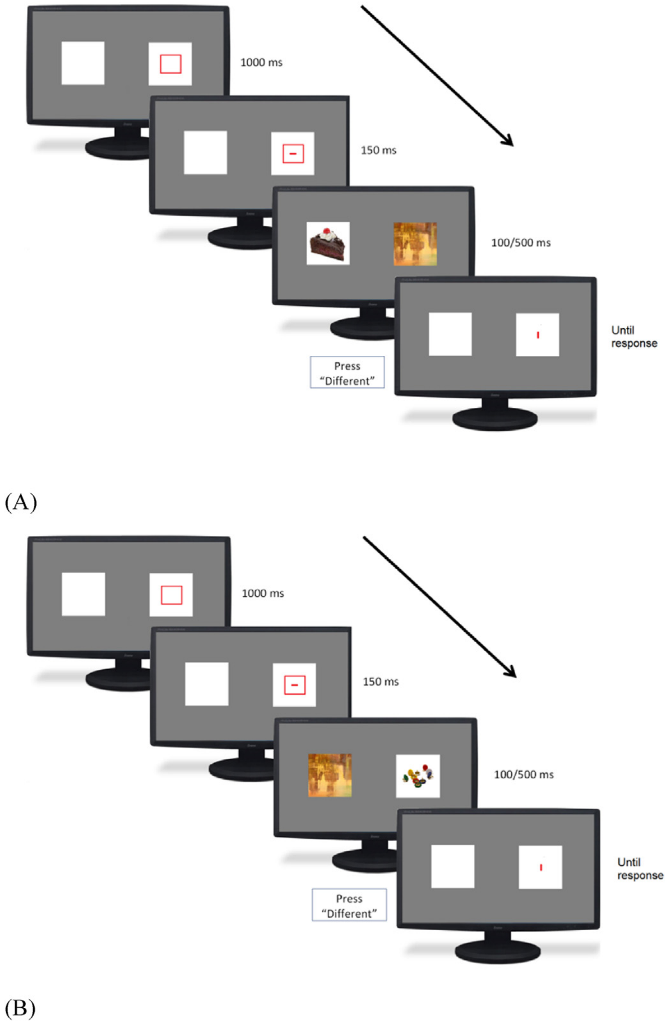

Fig. 1. Example of (A) a food trial where the food image appears distal to the anchor, the probe has a different position than the food image, and the orientation of the anchor and the probe is different; and (B) a neutral trial where the neutral image appears proximal to the anchor, the probe has a similar position as the neutral image, and the orientation of the anchor and the probe is different.

Stimuli. Food stimuli were 64 high caloric food items that were used previously in this task (Jonker, Glashouwer, et al., 2019). Of these, 32 were sweet high caloric food items (e.g., pancakes, cheese cake, and chocolate) selected from the *food-pics* database (Blechert, Meule, Busch, & Ohla, 2014), and 32 were savory high caloric food items (e.g., chips, fries, and pizza) of which 22 were selected from the food-pics database.[1] The additional 10 were selected from our own database and were

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[1] Images from food-pics database. Neutral: 1012; 1014; 1015; 1017; 1019; 1022; 1024; 1027; 1028; 1030; 1031; 1043; 1048; 1050; 1056; 1057; 1083; 1085; 1094; 1098; 1106; 1108; 1134; 1136; 1137; 1138; 1139; 1147; 1148; 1149; 1150; 1153; 1154; 1155; 1208; 1210; 1211; 1217; 1218; 1223; 1225; 1237; 1240; 1241; 1243; 1246; 1247; 1248; 1256; 1258; 1261; 1262; 1267; 1268; 1273; 1274; 1277; 1278; 5001; 5002; 5003; 5004; 5005; 5006. Food: 0001; 0002; 0016; 0018; 0021; 0025; 0041; 0046; 0052; 0058; 0060; 0068; 0072; 0101; 0103; 0104; 0107; 0110; 0111; 0113; 0116; 0117; 0137; 0145; 0148; 0151; 0155; 0157; 0158; 0159; 0161; 0165; 0173; 0174; 0175; 0184; 0186; 0188; 0296; 0309; 0310; 0313; 0317; 0318; 0339; 0350; 0354; 0510; 0465; 0471; 0503; 0505; 0507; 0523.

mostly food items specifically known to the Dutch population (e.g., croquette). Control images were 64 office or household related items such as a stapler, paperclips, and a bucket. All control images were selected from the food-pics database. The task also included 64 abstract art images, which were the same as in the original ARDPEI (Grafton & MacLeod, 2014).

Data reduction. Outliers were deleted following Grafton and MacLeod (2014), and this was done separately for the fasting and non-fasting group. Two participants from the non-fasting condition and four participants from the fasting condition were removed because they fell more than 2.58 SD below the mean number of correct responses. After removing these participants mean accuracy of the non-fasting and the fasting conditions were comparable (*Mean* = 94.5%, *SD* = 5%; *Mean* = 95.3%, *SD* = 4%, respectively). Incorrect trials were deleted. Of the correct trials, 2.4% in the non-fasting condition and 2.3% in the fasting condition fell more than 2.58 *SD* from the mean reaction time for that trial type and were therefore deleted. Lastly, reaction times faster than 200 ms, which are most likely anticipations errors, were deleted. This was limited to 5 trials in the non-fasting condition and 9 trials in the fasting condition. After data reduction of the ARDPEI there were 62 participants in the non-fasting condition and 61 in the fasting condition.

In total four AB scores were calculated, an engagement bias for the short (100 ms) and long (500 ms) Image Time trials, and a disengagement bias for the short and long Image Time trials. Engagement biases were calculated based on trials where participants had to look away from their initial focus point to see the representational image. Thus, on the trials in which the representational image position was distal from the anchor position. The difference in engagement bias was represented by the difference in reaction times of trials where the probe is in the same position as the image, and trials where the probe is in the opposite position. The engagement bias was calculated as follows:

> Engagement bias (higher scores reflect facilitated attention engagement with food compared to neutral cues) = (RT for probes in different location as food image – RT for probes in same location as food image) - (RT for probes in different location as neutral image – RT for probes in same location as neutral image).

The disengagement biases were calculated from trials in which participants' initial focus was on the position where the representational image appeared. Thus, from the trials in which the image position was proximal to the anchor position. The difference in difficulty to disengage was also represented by the difference in reaction times on trials were the probe appears in the same versus the opposite position. The disengagement bias was calculated as follows:

> Disengagement bias (higher scores reflect more difficulty to disengage from food compared to neutral cues) = (RT for probes in different location as food image – RT for probes in same location as food image) – (RT for probes in different location as neutral image – RT for probes in same location as neutral image).

Internal consistency. Internal consistency of the ARDPEI was assessed by performing split-half reliability analyses. The relationship between the first and second half of the attentional engagement on the short Image Time trials (Spearman- Brown = .23), on the long Image Time trials (Spearman- Brown= .04), and attentional disengagement on the short Image Time trials (Spearman- Brown = .16), and on the long Image Time trials (Spearman- Brown = . 27) were weak.

2.3. Procedure

The study protocol was approved by the ethical committee of the psychology department of the University of Groningen (17374). Participants signed up for the study through the screening during which they also provided informed consent. Women who reported to have a healthy BMI on the screening were randomly assigned to either the fasting or the non-fasting condition. To inform participants about their assigned condition and the corresponding instructions, and to increase compliance, participants received instructions via telephone from the researcher 1–5 days preceding their scheduled session. They additionally received an email with the instructions of the relevant condition. Participants who were assigned to the fasting condition were instructed to abstain from food, including drinks containing sugar, for at least 14 h prior to their appointment. Participants who were assigned to the non-fasting condition were instructed to have breakfast just before, but no later than half an hour prior to, their appointment. Participants in both conditions were instructed to not drink alcohol for at least 14 h prior to their appointment. Sessions were scheduled at 9 a.m. or 10.30 a.m.

For both conditions the lab session followed the same fixed order. First, participants answered the hunger scale to assess compliance. Following, they completed the ARDPEI. Finally, they completed the EDE-Q and an explicit question about study compliance. Lastly, their weight and height were measured. This study is part of a larger project additionally consisting of the Affective Simon Task (De Houwer, Crombez, Baeyens, & Hermans, 2001) completed after the ARDPEI, the Profile of Mood Scales (POMS-40; Grove & Prapavessis, 1992), and Restraint Scale (Herman & Polivy, 1975) administered before the EDE-Q. The study took about 50 min to complete and participants received study credits (n = 14) or financial compensation (n = 115).

2.4. Analyses

To test the hypothesis that individuals who have just eaten do not show more attention to food cues than to neutral cues, the attentional engagement and attentional disengagement scores of the satiated individuals were tested against zero with one sample *t*-tests. To test the hypothesis that individuals who have fasted do show more attention to food cues than neutral cues the attentional engagement and attentional disengagement scores of the fasted individuals were tested against zero with one sample *t*-tests. Further, on top of testing the presence and absence of attentional biases in the two groups, independent samples *t*-tests were performed to examine whether the attentional bias in the fasted group is larger than in the satiated group. To correct for familywise error rate for testing our hypotheses with four tests (engagement short, engagement long, disengagement short and disengagement long), we applied a Bonferroni-Holm correction. This means that the smallest *p*-value will be tested against an alpha of .0125, the *p*-values following against .016 and .025, respectively, and the largest against .05.To complement the results of the statistical analyses following the common frequentist approach, results were also reported with the Bayesian approach. Whereas the frequentist approach tests the probability of the data given one's hypothesis, the Bayesian approach tests the probability of the hypothesis given the data. Although the analyses following the frequentist approach have 95% power to find a medium effect size, the power for a small effect size is only 25%. Complementing these analyses with the Bayesian approach increases the confidence in our results. Most importantly, the Bayesian approach is able to test the evidence in favor of the null-hypothesis, which in the case of our examination of the attentional bias in the non-fasting group is what we are interested in. Bayesian analyses were conducted with JASP (JASP Team, 2018). Prior was set at the recommended default r = .707 (Wagenmakers et al., 2017).

In line with our hypotheses we reported $BF_{01,}$ which quantifies the evidence for the null hypothesis over the alternative hypotheses when examining the one sample *t*-tests in the non-fasting group, and $BF_{10,}$ which quantifies the evidence for the alternative hypotheses over the null hypotheses when examining the one sample *t*-tests in the fasting group. We also reported BF_{10} when examining differences between the groups. A Bayes factor of 1 is considered *no evidence*, between 1 and 3 *anecdotal*, between 3 and 10 *moderate*, between 10 and 30 *strong*, between 30 and 100 *very strong*, and more than 100 *extreme* evidence that the data are more likely under the alternative hypothesis. A Bayes factor between 1/3–1 is considered *anecdotal*, between 1/10–1/3 *moderate*, between 1/30–1/10 *strong*, between 1/100–1/30 *very strong*, and less than 1/100 *extremely strong* evidence that the data are more likely under null hypothesis (Wagenmakers et al., 2017).

3. Results

3.1. Compliance

Six participants in the fasted condition reported to have eaten shortly before their appointment in the lab (0.25–1.5 h before), and were therefore excluded from the analyses. There were some additional participants in the fasting condition with a fasting duration between 8 and 13 h ($n = 8$). However, since this is still a substantial fast, and also more than the minimum fasting period in other previous we decided to leave these participants in (Castellanos et al., 2009; Nijs & Franken, 2012; Stamataki et al., 2019). Additionally, one participant in the satiated condition reported to not have eaten the morning before the experiment (12.25 h before), and was therefore also excluded from the analyses. Further, when measuring height and weight in the lab three participants were underweight (BMI < 18.5; 1 in satiated and 2 in fasted condition) and nine participants were overweight (BMI > 25; 6 in satiated and 3 in fasted condition). These participants were therefore excluded from the analyses. This leaves 54 participants in the satiated and 50 in the fasted condition. This results in a power of 88.5% to find medium effects in the fasted condition, and 91% to find medium effects in the satiated condition.

3.2. Descriptive statistics

Group characteristics can be found in Table 1. As an indication that the manipulation was successful, there was a large difference between fasted and satiated individuals with regard to the number of hours that passed since they last ate ($t(102) = -45.45, p < .001$). Furthermore, fasted individuals also reported higher subjective hunger than satiated individuals ($t(102) = -11.28, p < .001$).

3.3. No attentional bias to food cues in satiated healthy weight individuals?

There is indeed evidence that the satiated individuals did not show stronger attentional engagement to food cues than neutral cues or more difficulty to disengage from food cues than from neutral cues (Table 2). This was the case for both the short or long image time trials. The frequentist approach shows that null hypotheses (i.e., indexes are not larger than zero) cannot be rejected. The Bayesian approach showed strong evidence that satiated individuals did not show stronger attentional engagement to food cues or attentional disengagement from food cues compared to neutral cues on the short image time trials, and moderate evidence that satiated individuals did not show stronger engagement to food cues or disengagement from food cues compared to neutral cues on the long image time trials.

Table 1
Group characteristics.

	Satiated ($n = 54$)		Fasted ($n = 50$)	
	Mean	SD	Mean	SD
Age	21.50	2.33	22.94	3.57
BMI	21.74	1.68	21.45	1.48
EDE-Q	1.62	1.04	1.59	1.05
Time since eaten	0.95	0.59	14.01	2.02
Subjective hunger	2.06	1.22	4.88	1.34

Note. EDE-Q = Eating Disorder Examination Questionnaire.

Table 2
Attentional bias in satiated healthy weight individuals and fasted healthy weight individuals.

	Satiated (n = 54)			
	Mean	SD	t (p)	BF01
Engagement short	−8.52	99.75	−0.63 (.734)	10.30
Engagement long	3.48	95.54	0.27 (.395)	5.40
Disengagement short	−10.18	100.71	−0.74 (.770)	11.00
Disengagement long	−5.85	78.61	−0.55 (.707)	9.81
	Fasted (n = 50) Mean	SD	t (p)	BF10
Engagement short	32.85	101.93	2.28 (.014)	3.18
Engagement long	−7.93	101.10	−0.55 (.709)	0.11
Disengagement short	2.54	99.68	0.18 (.429)	0.18
Disengagement long	−12.12	95.34	−0.90 (.813)	0.09

3.4. Attentional bias to food cues in fasted healthy weight individuals?

There is indeed indication for an attentional bias to food cues in fasted individuals. Following the frequentist approach, it seems that fasted individuals showed stronger attentional engagement to food cues than neutral cues on the short image time trials, although this finding did not reach statistical significance ($p = .014$, $\alpha = .0125$). The Bayes factor showed moderate evidence for more attentional engagement with food cues than neutral cues in fasted individuals. Fasted individuals did not seem to have an attentional bias for food compared to neutral stimuli as indexed by attentional engagement on the long image time trials and attentional disengagement on both the short and long image time trials. The frequentist approach showed no evidence for the alternative hypotheses that there is an attentional bias, and the Bayesian approach showed moderate to strong evidence that fasted individuals did not have an attentional disengagement bias on the short and long image time trials, or an attentional engagement bias on the long image time trials.

3.5. Do fasted healthy weight individuals have a stronger attentional bias to food cues than satiated healthy weight individuals?

Independent samples *t*-tests showed the same pattern as the one sample *t*-tests. That is, the frequentist approach showed a marginally significant difference between fasted and satiated individuals, but only on the attentional engagement measure with short cue delay (Table 3). Bayesian analyses showed anecdotal evidence that fasted individuals had more attentional engagement to food cues than satiated individuals.

4. Discussion

This study set out to examine the assumption that healthy weight individuals who are deprived of food have an AB to food cues, whereas healthy weight individuals who are satiated do not show an AB to food. In contrast to previous studies, we included a sufficient sample size to detect medium effects, performed Bayesian analyses allowing to

Table 3
Differences between individuals in fasted and satiated condition.

	Between-groups test		
	t (p)	Cohen's d	BF_{10}
Engagement short	2.09 (0.019)	0.41	2.78
Engagement long	−0.59 (0.722)	−0.12	0.14
Disengagement short	0.65 (0.260)	0.13	0.36
Disengagement long	−0.37 (0.643)	−0.07	0.16

examine the evidence in favor of the null-hypothesis, and used an AB measure designed to differentiate between engagement and disengagement (Grafton & MacLeod, 2014). Our findings can be summarized as follows: 1) there was moderate to strong evidence that satiated healthy weight women do not show more attention to food cues than to neutral cues; 2) there was moderate evidence that fasted healthy weight women show stronger attentional engagement to food cues than to neutral cues when these cues are shown briefly (100 ms), but no attentional engagement bias when cues are shown longer (500 ms) or attentional disengagement bias to food cues; 3) there was anecdotal evidence for a difference in attentional engagement to food cues between healthy weight women who fasted and satiated healthy weight individuals when cues were shown briefly (100 ms).

In line with expectations, findings indicate that satiated healthy weight women do not have an AB to food cues. The Bayes factors showed that there is moderate to strong evidence that healthy weight women who are satiated do not have a stronger attentional engagement or attentional disengagement bias to food cues than to neutral cues. Further, the current study showed moderate evidence that women who fasted for an average of 14 h showed stronger attentional engagement to food cues than to neutral cues when these cues were shown briefly (100 ms). These findings seem to be consistent with the expectation that food stimuli are attention grabbing because of their rewarding value in food-deprived situations, and that they have less rewarding value when individuals are satiated (Berridge et al., 2010; Higgs et al., 2017; Pool et al., 2016). It should however be acknowledged that the presence of AB to food cues per se does not imply that food cues are considered rewarding, as stimuli with negative saliency are also expected to result in heightened attention (Field et al., 2016; Pool et al., 2016).

Interestingly, fasted healthy weight individuals only showed attentional engagement to food cues that were shown briefly (100 ms), but not to food cues that were shown longer (500 ms). Until now, there was only inconsistent empirical evidence for a role of hunger in the attentional bias to food cues in healthy weight individuals. Further, the studies used overt (i.e., eye-tracking) and covert (RT measures) attention as index of attentional bias making comparison across studies difficult, since it is not uncommon that different results are found with overt and covert outcome indices of the same task (e.g., Motoki, Saito, Nouchi, Kawashima, & Sugiura, 2018). Nevertheless, when comparing current findings with other findings from covert attention measures there seems to be a relatively consistent pattern. That is, a previous study using the VPT with stimuli that were shown for 100 or 500 ms also found an ABto food cues in individuals who were food deprived (Nijs, Franken, & Muris, 2010), yet a study using the VPT with stimuli that were shown for 2000 ms did not (Castellanos et al., 2009). Together with our current findings, these findings thus seem to indicate that an ABto food cues in food deprived individuals might only be apparent when the food images are shown briefly. This might indicate that participants are able to ignore food cues and to focus on the task at hand when there is sufficient opportunity for cognitive control.

The current study showed moderate to strong evidence that fasted individuals did not have an attentional disengagement bias to food cues. Thus, it seems that only attentional engagement and not attentional disengagement might be influenced by hunger in healthy weight individuals. This seems to be in line with the findings from a previous study using the ARDPEI in the context of food (Jonker, Glashouwer, et al., 2019). In that study, healthy weight adolescents also showed an AB to food cues only on the attentional engagement trials where cues were shown briefly (100 ms), and not on attentional disengagement trials. Healthy weight individuals in this previous study were food deprived for about 3 h[2] before performing the attentional bias task. Although this is substantially shorter than individuals in the current study, it has been shown that fasting for 3 h or more already resulted in substantial differences in hunger among healthy weight individuals (Sawada, Sato, Minemoto, & Fushiki, 2019). Given these findings, it thus seems that specifically attentional engagement might be involved in eating behavior of healthy weight individuals.

The current study provides some important implications for future research on AB to food cues in the context of for example obesity. First, taking satiation into account seems important. For example, when the expectation is that individuals with obesity have more attention to food cues than healthy weight individuals, outcomes of such a comparison will likely differ based on whether obese individuals are compared to satiated or fasted healthy weight individuals. Further, also the influence of satiation on AB in obese individuals should be examined in more depth. Although it was suggested that obese individuals might have an AB to food cues when hungry but also when satiated, studies thus far have not shown consistent findings (Castellanos et al., 2009; Nijs et al., 2010; Stamataki et al., 2019). Second, it seems to be important to differentiate between attentional engagement and disengagement when examining attentional bias to food cues in the context of eating behavior. Thus far, studies on AB to food cues in healthy weight individuals seem to show that specifically attentional engagement might be important (Jonker, Glashouwer, et al., 2019). Nevertheless, it might be premature to conclude that attentional disengagement is not relevant in the context of eating behavior. For example, it might be that attentional disengagement bias is related to overeating and obesity.

The current study has some limitations that should be taken into account when interpreting the results. First, although we initially included 64 women in the non-fasting and 65 individuals in the fasting condition, and substantial measures were taken to counteract non-compliance, after exclusion based on the ARDPEI outlier procedure, non-compliance to the manipulation, and BMI as measured in the lab, a sample of 54 individuals in the non-fasting and 50 in the fasting condition remained. Although this still resulted in a substantial power to find medium effects, it was lower than intended. Furthermore, the evidence for stronger attentional engagement to food cues than to neutral cues in fasted individuals was moderate. It thus seems important to replicate the findings of the current study.

Second, the ARDPEI showed low internal consistency, which might negatively influence the interpretability of the results (Parsons, Kruijt, & Fox, 2018). Task characteristics such as using a range of stimuli that might not all be relevant to individuals, and the randomized order of trials might account for this low internal consistency (Ataya et al., 2012; Christiansen, Mansfield, Duckworth, Field, & Jones, 2015). Further, AB indices calculated from the ARDPEI are difference scores of four different trial types that each contain true and noise variance. Last, a potential issue with the internal consistency of AB measures in general is that they are based on difference scores. The components of these difference scores are often correlated, for example because individuals' average speed of responding is included in all components. When components of such a difference score are highly correlated the reliability of this difference score will be low (Thomas & Zumbo, 2011). Nevertheless, since the AB measures are not used as individual difference variables in the current design, the most crucial aspect of the task is that it is sensitive enough to pick up a difference in attention for food and neutral stimuli on a group level. Furthermore, the ARPDEI does seem to provide consistent results when comparing current findings to a previous study using the ARDPEI (Jonker, Glashouwer, et al., 2019).

Taken together, the current study provides evidence for an AB for food cues in fasted healthy weight women and an absence of such a bias in satiated healthy weight women. Fasted healthy weight women showed attentional engagement to food cues that were shown briefly (100 ms), but not to food cues that were shown longer (500 ms). Furthermore, fasted healthy weight women did not show more difficulty to disengage attention from food cues than from neutral cues. Satiated healthy weight individuals did not show an attentional

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[2] The healthy weight group in this study ate on average 2 h and 14 min before entering the study. However, the ARDPEI was performed around 45 min after entering the study.

engagement or disengagement bias. These findings are in line with the assumption that an AB for food cues might play a role in eating behavior of healthy weight women. Further, they seem to show that attentional engagement to food cues is only stronger in hungry individuals when there is little room for cognitive control. Lastly, our findings point to the relevance of differentiating between attentional engagement and attentional disengagement.

Ethical statement

The study protocol was approved by the ethical committee of the psychology department of the University of Groningen (17374). Participants signed up for the study through the screening during which they also provided informed consent.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2020.104686.

References

Aardoom, J. J., Dingemans, A. E., Slof Op't Landt, M. C. T., & Van Furth, E. F. (2012). Norms and discriminative validity of the eating disorder examination questionnaire (EDE-Q). *Eating Behaviors, 13*, 305–309. https://doi.org/10.1016/j.eatbeh.2012.09.002.

Anderson, B. A. (2017). Going for it: The economics of automaticity in perception and action. *Current Directions in Psychological Science, 26*, 140–145. https://doi.org/10.1177/0963721416686181.

Ataya, A. F., Adams, S., Mullings, E., Cooper, R. M., Attwood, A. S., & Munafò, M. R. (2012). Internal reliability of measures of substance-related cognitive bias. *Drug and Alcohol Dependence, 121*, 148–151. https://doi.org/10.1016/j.drugalcdep.2011.08.023.

Berridge, K. C. (2009). "Liking" and "wanting" food rewards: Brain substrates and roles in eating disorders. *Physiology & Behavior, 97*, 537–550. https://doi.org/10.1016/j.physbeh.2009.02.044.

Berridge, K. C., Ho, C. Y., Richard, J. M., & Difeliceantonio, A. G. (2010). The tempted brain eats: Pleasure and desire circuits in obesity and eating disorders. *Brain Research, 1350*, 43–64. https://doi.org/10.1016/j.brainres.2010.04.003.

Blechert, J., Meule, A., Busch, N. A., & Ohla, K. (2014). Food-pics: An image database for experimental research on eating and appetite. *Frontiers in Psychology, 5*, 1–10. https://doi.org/10.3389/fpsyg.2014.00617.

Boutelle, K. N., Kuckertz, J. M., Carlson, J., & Amir, N. (2014). A pilot study evaluating a one-session attention modification training to decrease overeating in obese children. *Appetite, 76*, 180–185. https://doi.org/10.1016/j.appet.2014.01.075.

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., et al. (2013). Power failure: Why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience, 14*, 365–376. https://doi.org/10.1038/nrn3475.

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., et al. (2009). Obese adults have visual attention bias for food cue images: Evidence for altered reward system function. *International Journal of Obesity, 33*, 1063–1073. https://doi.org/10.1038/ijo.2009.138.

Christiansen, P., Mansfield, R., Duckworth, J., Field, M., & Jones, A. (2015). Internal reliability of the alcohol-related visual probe task is increased by utilising personalised stimuli and eye-tracking. *Drug and Alcohol Dependence, 155*, 170–174. https://doi.org/10.1016/j.drugalcdep.2015.07.672.

De Houwer, J., Crombez, G., Baeyens, F., & Hermans, D. (2001). On the generality of the affective Simon effect. *Cognition & Emotion, 15*, 189–206. https://doi.org/10.1080/02699930125883.

De Ridder, D., Adriaanse, M., Evers, C., & Verhoeven, A. (2014). Who diets? Most people and especially when they worry about food. *Appetite, 80*, 103–108. https://doi.org/10.1016/j.appet.2014.05.011.

Fairburn, C. G., & Beglin, S. (2008). Eating disorder examination questionnaire (EDE-Q 6.0). In C. G. Fairburn (Ed.). *Cognitive behavior therapy and eating disorders*. New York: Guilford Press.

Field, M., Werthmann, J., & Franken, I. H. A. (2016). The role of attentional bias in obesity and addiction. *Health Psychology, 35*, 767–780. https://doi.org/10.1017/CBO9781107415324.004.

Franken, I. H. A. (2003). Drug craving and addiction: Integrating psychological and neuropsychopharmacological approaches. *Progress in Neuro-Psychopharmacology & Biological Psychiatry, 27*, 563–579. https://doi.org/10.1016/S0278-5846(03)00081-2.

Grafton, B., & MacLeod, C. (2014). Enhanced probing of attentional bias: The independence of anxiety-linked selectivity in attentional engagement with and disengagement from negative information. *Cognition & Emotion, 28*, 1287–1302. https://doi.org/10.1080/02699931.2014.881326.

Grand, S. (1968). Color-word interference: II. An investigation of the role of vocal conflict and hunger in associative priming. *Journal of Experimental Psychology, 77*, 31–40. https://doi.org/10.1037/h0025759.

Grove, J. R., & Prapavessis, H. (1992). Preliminary evidence for the reliability and validity of an abbreviated Profile of Mood States. *International Journal of Sport Psychology, 23*, 93–109. https://doi.org/10.1037/1040-3590.7.1.80.

Herman, C. P., & Polivy, J. (1975). Anxiety, restraint and eating behaviour. *Journal of Abnormal Psychology, 84*, 666–672. https://doi.org/10.1037//0021-843X.84.6.666.

Higgs, S., Spetter, M. S., Thomas, J. M., Rotshtein, P., Lee, M., Hallschmid, M., et al. (2017). Interactions between metabolic, reward and cognitive processes in appetite control: Implications for novel weight management therapies. *Journal of Psychopharmacology, 31*, 1460–1474. https://doi.org/10.1177/0269881117736917.

Hummel, G., Ehret, J., Zerweck, I., Winter, S. S., & Stroebele-Benschop, N. (2018). How eating behavior, food stimuli and gender may affect visual attention – an eye tracking study. *Eating Behaviors, 31*, 60–67. https://doi.org/10.1016/j.eatbeh.2018.08.002.

Jonker, N. C., Glashouwer, K. A., Hoekzema, A., Ostafin, B. D., & De Jong, P. J. (2019a). Attentional engagement with and disengagement from food cues in Anorexia Nervosa. *Behaviour Research and Therapy, 114*, 15–24. https://doi.org/10.1016/j.brat.2019.01.003.

Jonker, N. C., Heitmann, J., Ostafin, B. D., MacLeod, C., Glashouwer, K. A., & de Jong, P. J. (2019b). A new approach to facilitating attentional disengagement from food cues in unsuccessful dieters: The bouncing image training task. *Behaviour Research and Therapy, 120*, 103445. https://doi.org/10.1016/j.brat.2019.103445.

Kemps, E., Tiggemann, M., & Hollitt, S. (2014). Biased attentional processing of food cues and modification in obese individuals biased attentional processing of food cues and modification in obese individuals. *Health Psychology, 33*, 1391–1401.

Knäuper, B., Cheema, S., Rabiau, M., & Borten, O. (2005). Self-set dieting rules: Adherence and prediction of weight loss success. *Appetite, 44*, 283–288. https://doi.org/10.1016/j.appet.2005.01.008.

Loeber, S., Grosshans, M., Herpertz, S., Kiefer, F., & Herpertz, S. C. (2013). Hunger modulates behavioral disinhibition and attention allocation to food-associated cues in normal-weight controls. *Appetite, 71*, 32–39. https://doi.org/10.1016/j.appet.2013.07.008.

Loeber, S., Grosshans, M., Korucuoglu, O., Vollmert, C., Vollstädt-Klein, S., Schneider, S., et al. (2012). Impairment of inhibitory control in response to food-associated cues and attentional bias of obese participants and normal-weight controls. *International Journal of Obesity, 36*, 1334–1339. https://doi.org/10.1038/ijo.2011.184.

Mogg, K., & Bradley, B. P. (2016). Anxiety and attention to threat: Cognitive mechanisms and treatment with attention bias modification. *Behaviour Research and Therapy, 87*, 76–108. https://doi.org/10.1016/j.brat.2016.08.001.

Mogg, K., Bradley, B. P., Hyare, H., & Lee, S. (1998). Selective attention to food-related stimuli in hunger: Are attentional biases specific to emotional and psychopathological states, or are they also found in normal drive states? *Behaviour Research and Therapy, 36*, 227–237. https://doi.org/10.1016/S0005-7967(97)00062-4.

Motoki, K., Saito, T., Nouchi, R., Kawashima, R., & Sugiura, M. (2018). Tastiness but not healthfulness captures automatic visual attention: Preliminary evidence from an eye-tracking study. *Food Quality and Preference, 64*(May 2017), 148–153. https://doi.org/10.1016/j.foodqual.2017.09.014.

Nijs, I. M. T., & Franken, I. H. A. (2012). Attentional processing of food cues in overweight and obese individuals. *Current Obesity Reports, 1*, 106–113. https://doi.org/10.1007/s13679-012-0011-1.

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2010a). Food-related stroop interference in obese and normal-weight individuals: Behavioral and electrophysiological indices. *Eating Behaviors, 11*, 258–265. https://doi.org/10.1016/j.eatbeh.2010.07.002.

Nijs, I. M. T., Muris, P., Euser, A. S., & Franken, I. H. A. (2010b). Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite, 54*, 243–254. https://doi.org/10.1016/j.appet.2009.11.004.

Parsons, S., Kruijt, A.-W., & Fox, E. (2018). *Psychological Science needs a standard practice of reporting the reliability of cognitive behavioural measurements*, *Vols. 1–25*https://doi.org/10.31234/osf.io/6ka9z.

Polivy, J., Herman, C. P., & Coelho, J. S. (2008). Caloric restriction in the presence of attractive food cues: External cues, eating, and weight. *Physiology & Behavior, 94*, 729–733. https://doi.org/10.1016/j.physbeh.2008.04.010.

Pool, E., Brosch, T., Delplanque, S., & Sander, D. (2016). Attentional bias for positive emotional stimuli: A meta-analytic investigation. *Psychological Bulletin, 142*, 79–106. https://doi.org/10.1037/bul0000026.

Posner, M. I., Inhoff, A. W., & Friedrich, F. J. (1987). Isolating attentional systems: A cognitive-anatomical analysis. *Psychobiology, 15*, 107–121.

Robinson, T. E., & Berridge, K. C. (2001). Mechanisms of action of addictive stimuli incentive-sensitization and addiction. *Addiction, 96*, 103–114. https://doi.org/10.1080/09652140020016996.

Sawada, R., Sato, W., Minemoto, K., & Fushiki, T. (2019). Hunger promotes the detection of high-fat food. *Appetite, 142*(June), 104377. https://doi.org/10.1016/j.appet.2019.104377.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). E-Prime reference guide. *Psychology Software Tools, 3*. https://doi.org/10.1186/1756-0381-3-1.

Small, D. M., Zatorre, R. J., Dagher, A., Evans, A. C., & Jones-Gotman, M. (2001). Changes in brain activity related to eating chocolate: From pleasure to aversion. *Brain, 124*, 1720–1733. https://doi.org/10.1093/brain/124.9.1720.

Stamataki, N. S., Elliott, R., McKie, S., & McLaughlin, J. T. (2019). Attentional bias to food varies as a function of metabolic state independent of weight status. *Appetite, 143*, 104388. https://doi.org/10.1016/j.appet.2019.104388.

Stice, E., Lawrence, N. S., Kemps, E., & Veling, H. (2016). Training motor responses to food: A novel treatment for obesity targeting implicit processes. *Clinical Psychology Review, 49*, 16–27. https://doi.org/10.1016/j.cpr.2016.06.005.

Thomas, D. R., & Zumbo, B. D. (2011). Difference scores from the point of view of reliability and repeated-measures ANOVA. *Educational and Psychological Measurement, 72*, 37–43. https://doi.org/10.1177/0013164411409929.

Verbeken, S., Braet, C., Naets, T., Houben, K., Boendermaker, W., & Zeepreventorium, vzw (2018). Computer training of attention and inhibition for youngsters with obesity: A pilot study. *Appetite, 123*, 439–447.

Wagenmakers, E. J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., et al. (2017). Bayesian inference for psychology. Part II: Example applications with JASP. *Psychonomic Bulletin & Review, 25*, 58–76. https://doi.org/10.3758/s13423-017-1323-7.

Wardle, J., Haase, A. M., & Steptoe, A. (2006). Body image and weight control in young adults: International comparisons in university students from 22 countries. *International Journal of Obesity, 30*, 644–651. https://doi.org/10.1038/sj.ijo.0803050.

Werthmann, J., Roefs, A., Nederkoorn, C., Mogg, K., Bradley, B. P., & Jansen, A. (2011). Can(not) take my eyes off it: Attention bias for food in overweight participants. *Health Psychology, 30*, 561–569. https://doi.org/10.1037/a0024291.

Wing, R. R., & Phelan, S. (2005). Long-term weight loss maintenance. *American Journal of Clinical Nutrition, 82*, 222S–225S. https://doi.org/10.1093/ajcn/82.1.222S.

World Health Organisation (2018). Obesity and overweight. http://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight, Accessed date: 11 July 2018.