J. Behav. Ther. & Exp. Psychiat. 45 (2014) 136–143

Contents lists available at ScienceDirect

Journal of Behavior Therapy and Experimental Psychiatry

journal homepage: www.elsevier.com/locate/jbtep

Attention bias for chocolate increases chocolate consumption – An attention bias modification study

Jessica Werthmann [a,*], Matt Field [b], Anne Roefs [a], Chantal Nederkoorn [a], Anita Jansen [a]

[a] Faculty of Psychology & Neuroscience, Maastricht University, Maastricht, The Netherlands
[b] School of Psychology, University of Liverpool, Liverpool, United Kingdom

ARTICLE INFO

Article history:
Received 26 April 2013
Received in revised form
13 September 2013
Accepted 18 September 2013

Keywords:
Attention bias
Attention modification
Chocolate
Antisaccade task
Eye-tracking
Overeating

ABSTRACT

Objective: The current study examined experimentally whether a manipulated attention bias for food cues increases craving, chocolate intake and motivation to search for hidden chocolates.
Method: To test the effect of attention for food on subsequent chocolate intake, attention for chocolate was experimentally modified by instructing participants to look at chocolate stimuli ("attend chocolate" group) or at non-food stimuli ("attend shoes" group) during a novel attention bias modification task (antisaccade task). Chocolate consumption, changes in craving and search time for hidden chocolates were assessed. Eye-movement recordings were used to monitor the accuracy during the experimental attention modification task as possible moderator of effects. Regression analyses were conducted to test the effect of attention modification and modification accuracy on chocolate intake, craving and motivation to search for hidden chocolates.
Results: Results showed that participants with higher accuracy (+1 SD), ate more chocolate when they had to attend to chocolate and ate less chocolate when they had to attend to non-food stimuli. In contrast, for participants with lower accuracy (−1 SD), the results were exactly reversed. No effects of the experimental attention modification on craving or search time for hidden chocolates were found.
Limitation: We used chocolate as food stimuli so it remains unclear how our findings generalize to other types of food.
Conclusion: These findings demonstrate further evidence for a link between attention for food and food intake, and provide an indication about the direction of this relationship.

In an obesogenic food environment, as present in the western world, we are constantly surrounded by an abundance of palatable food cues. Ignoring or attending to these food cues may influence our eating behaviour. For example, imagine you are walking through the main shopping street of your town on a Saturday: If you notice all the delicious food cues from shops or restaurants you may end up consuming a lot of high caloric food, such as waffles, French fries and hamburgers. If you focus instead on shoes in shop windows, ignoring all food cues, you might end up with a full shoe cabinet, but probably not with a full stomach.

Attention for delicious, yet unhealthy, food temptations could contribute to a lack of control over food intake, for example by facilitating overeating or food intake of unhealthy snacks. Indeed, evidence from several studies measuring attentional bias for food suggests that attention for food is related to obesity and craving for food. For example, neuroimaging studies showed that a greater activation of reward and attention centres in the brain during food exposure is related to obesity, poorer weight control and weight gain (Murdaugh, Cox, Cook, & Weller, 2012; Stice, Yokum, Bohon, Marti, & Smolen, 2010; Yokum, Ng, & Stice, 2011). In addition, elevated attention biases for food cues have been observed in overweight and obese samples in comparison to participants with a healthy weight (e.g., Castellanos et al., 2009; Nijs, Franken, & Muris, 2010; Werthmann et al., 2011). Moreover, several studies showed that attention biases for food are related to hunger and craving in healthy weight and overweight participants (e.g., Kemps & Tiggemann, 2009; Mogg, Bradley, Hyare, & Lee, 1998; Nijs, Muris, Euser, & Franken, 2010; Piech, Pastorino, & Zald, 2010; Smeets, Roefs, & Jansen, 2009; Werthmann et al., 2011). Thus, evidence from these cross-sectional studies establishes an association of attention for food and eating-related behaviours or increased BMI but did not test the hypothesized causal relation of attention bias and food intake.

* Corresponding author. Tel.: +31 433884558; fax: +31 433884196.
E-mail address: Jessica.Werthmann@maastrichtuniversity.nl (J. Werthmann).

0005-7916/$ – see front matter
http://dx.doi.org/10.1016/j.jbtep.2013.09.009

There is preliminary evidence suggesting that changes in attention for food cues may be causally related to changes in eating behaviour: one previous study that manipulated attention focus for food after a body image challenge (i.e., confronting participants with advertisements of thin models and body parts) showed that attending high caloric food words elevated the chance to choose low caloric over high caloric cookies, in comparison to participants who attended neutral words (Smith & Rieger, 2009). This finding suggests that attending to high calorie foods and being exposed to body image comparisons could activate dietary restraint. However, because attention to food was manipulated in the context of body image satisfaction and because the amount of cookies was fixed, this study does not inform about the relation of purely the attention for food and the amount of food intake.

Thus, given the correlational nature of most previous studies, the causal impact of attention for food cues on food intake remains unclear, and this question can only be addressed by experimentally manipulating attentional bias followed by a measure of food intake. The aim of the current study was therefore to manipulate attention bias for food cues, to test whether a causal relationship exists between manipulated attention for food on the one hand and craving and food intake on the other hand.

Experimentally inducing changes in attentional processes to affect subsequent behaviour has been termed attention bias modification (ABM). This method has been explored extensively in the field of anxiety research. Several studies have shown that training attention away from threatening stimuli reduced an attentional bias for these cues and led to a decrease in anxiety symptoms in adults and children in comparison to a control group (Bar-Haim, Morag, & Glickman, 2011; Hakamata et al., 2010; Hallion & Ruscio, 2011; Mathews & MacLeod, 2002).

Typically, ABM studies have relied on a modified version of the visual-probe paradigm as training. During this task, two stimuli (symptom-relevant/neutral) are presented side by side on a computer screen, and then a probe appears in the location of one of the stimuli. Participants are instructed to react to the probe by a manual response. To manipulate attention towards (or away) from disorder-related cues, the probe replaces the relevant stimuli in 100% (or 0%) of all trials. The rationale of the training presumes that an implicit learning process is elicited through attending to the systematic contingencies, which improves task performance, thereby gradually modifying an attention bias towards (or away from) the disorder-relevant cue (Bar-Haim, 2010). However, one disadvantage of modifying the visual probe paradigm in this way is that it modifies attention processes indirectly by manipulating and measuring the manual response reactions. Yet, targeting visual attention processes directly by the modification procedure and simultaneously monitoring visual attention as measure for modification accuracy, for example by recording eye movements, could provide a more precise modification of attention.

One alternative approach to manipulate attention biases, which overcomes the disadvantage of modifying attention indirectly, is a modified antisaccade task in combination with the assessment of eye-movements. Saccades are rapid eye-movements (e.g., Munoz & Everling, 2004). Saccadic eye-movements are closely related to visuo-spatial attentional engagement and represent a faster measure for attentional processing than the recordings of response reactions (e.g., Bannerman, Milders, de Gelder, & Sahraie, 2009; Hutton, 2008; Munoz & Everling, 2004). The antisaccade task has typically been used as a measure of cognitive inhibitory control (e.g., Hallett, 1978; Hallett & Adams, 1980; or for a review Hutton, 2008). In general, the antisaccade task can be seen as a stimulus-response mapping task with regard to attentional processing: During the task participants are required to inhibit reflexive eye movements (saccades) towards a peripherally presented target, and have to shift their gaze in the opposite direction (i.e., perform an antisaccade). This process requires a top-down inhibitory cognitive control execution, because participants have to suppress their reflexive response (prosaccade towards target), and instead have to voluntarily initiate the inverse response by saccading towards the mirror position of the target (Munoz & Everling, 2004). Thus, this method provides the possibility to combine a direct modification of attention with the monitoring of accuracy by implementing recordings of eye-movements.

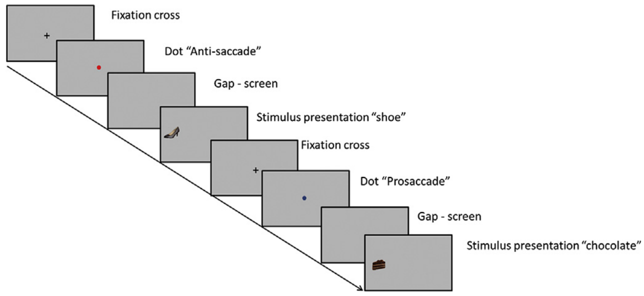

Fig. 1. Schematic presentation of trials during the modification task. Depending on the respective condition, participants had always to make a prosaccade towards chocolate and an anti-saccade away from shoes during the stimulus presentation (in the "attend chocolate condition", as depicted here) or they had always to make an anti-saccade away from chocolate and a pro-saccade towards shoes (in the "attend shoe" condition, not depicted).

In the present study, the standard antisaccade task was adapted to manipulate attention towards versus away from chocolate. The aim of the current study was to test experimentally if modification of attention for chocolate versus attention for shoes would contribute to differences in chocolate consumption, changes in craving or motivation to search for hidden chocolates (as indexed by search time). To modify attention allocation for chocolate versus neutral cues the contingencies of pro- and antisaccades towards or away from chocolate were altered: In the "attend chocolate" group, participants always had to perform a prosaccade towards chocolate stimuli and an antisaccade away from neutral stimuli (shoes), whereas in the "attend shoes" condition, participants always had to perform a prosaccade towards shoes and an antisaccade away from chocolate. We expected that participants in the "attend chocolate" group would consume more chocolate, report more craving and search longer for hidden chocolate, as index for higher motivation for chocolate, in comparison to participants in the "attend shoes" group.

Another advantage was that eye-movements were monitored during the anti-saccade task. This is the first study that applied a measure for the accuracy of attention during an attention modification procedure. Thus, we further tested if accuracy during the attention modification moderated the influence of modified attention on chocolate consumption, craving and search time for hidden chocolates.

1. Method

1.1. Participants

Female participants ($n = 56$) were recruited by flyers and the local electronic recruitment system. Only female students were eligible for participation to eliminate possible gender effects with regard to eating behaviour. All participants were undergraduate students. The study received ethical approval from the local ethics committee.

1.2. Materials and measures

1.2.1. Experimental attention modification: antisaccade task

Attentional bias for food cues was manipulated by a modified version of an anti-saccade task (e.g., Hallett, 1978). Saccadic eye movements were recorded during the task to check how accurately the participant followed the attention modification instructions (i.e., modification accuracy). The paradigm was programmed with Experiment Builder (SR Research Ltd., Mississauga, Ontario, Canada).

Each trial started with a black fixation point appearing in the middle of the screen, which dissolved directly after participants fixated on it for 500 ms. It was immediately replaced by either a red or blue fixation point which was presented in the central position for 1000 ms, followed by a 200 ms gap (blank screen), which helps to speed up reaction times (e.g., Kissler & Keil, 2008). The colour of this second fixation point informed participants whether to subsequently perform either a pro- (blue colour) or an antisaccade (red colour) to a pictorial stimulus (chocolate or shoe (neutral) pictures) that then appeared on either the left or right of the computer screen for 500 ms, see Fig. 1 for a graphical presentation.

1.2.1.1. Trial types. In total, each participant performed 320 trials, which were preceded by 40 practice trials. In the practice block, pro- and anti-saccade cues appeared before chocolate and shoe pictures equally often, that is, there were 10 chocolate prosaccade trials, 10 shoe prosaccade trials, 10 chocolate antisaccade trials and 10 shoe antisaccade trials. The practice block was followed by eight attention modification blocks, each containing 40 modification trials. In each block 20 chocolate pictures and 20 shoe pictures were presented. In the 'attend chocolate' condition, chocolate pictures were always presented after the prosaccade cue and shoe pictures were always presented after the antisaccade cue. These contingencies were reversed in the 'attend shoe' condition. The order of pro- and antisaccades trials was uniquely randomized for each participant within each block.

1.2.1.2. Stimuli. Chocolate stimuli consisted of 20 photographs of chocolate items. Shoe stimuli consisted of 20 photographs of shoes. Chocolate was contrasted with shoe stimuli, for two reasons: first, chocolate is regarded as palatable, yet forbidden food item and one of the food items particularly craved by women (Hetherington & Macdiarmid, 1993). We wanted to contrast chocolate with a non-food object that might in general be equally attractive for women, and decided therefore for shoes. Another reason for shoes as contrast category for chocolate stimuli was that both items were easy to match on colour. Accordingly, all stimuli were matched as closely as possible based on colour, complexity, brightness, object form and image size. The image size and position of stimuli were tested in a brief pilot study to ensure that participants in both conditions were able to recognize peripherally a stimulus as a chocolate or shoe photograph even if they had to perform an anti-saccade. Shoe photographs subtended at $5.33^\circ \times 5.12^\circ$, chocolate photographs subtended at $5.81^\circ \times 4.92^\circ$ on either the left or right side of a fixation circle (subtending at $0.95^\circ \times 0.95^\circ$), at a viewing distance of 50 cm. The position of chocolate and shoe cues (left or right of the centre) was fully counterbalanced within each block. All stimuli were presented against a light grey background (RGB colour spectrum: 191, 191, 191). All stimuli were presented on a Dell Optiplex™ 760 Computer with a 19 inch monitor (60 Hz refresh rate) in a dimly lit room.

1.2.2. Eye movements

Eye-movements were monitored to measure accuracy during the attention modification task. The rationale for including this assessment of accuracy was to test if accuracy during the modification moderates the impact of attention modification on subsequent chocolate intake, craving and search time for hidden chocolates. In addition, eye-movement data was used to test if the modification of attention led to the expected differences in attention for chocolate. Therefore, two attention variables were computed based on eye-movement recordings: (1) the accuracy of performance was calculated based on the overall percentage of correctly performed trials, comprising correct performance on both pro- and antisaccade trials during the attention modification. (2) dwell time on chocolate stimuli during chocolate trials was calculated by averaging fixation durations on chocolate images per trial over all chocolate trials, irrespective of correctly or incorrectly performed, and then calculated as percentage score of average total fixation time per trial. Dwell time provides a measure for attentional focus on chocolate images (see for a comparable measure e.g., Castellanos et al. (2009)).

1.2.3. Search task

A search for hidden chocolates was included as a new method to assess motivation for chocolate. Persistence in task performance is a common measure for motivation (Keatley, Clarke, & Hagger, 2012; Miller & Hom, 1990) and was thus included to assess the participants' motivation for chocolate. For this search task the experimenter left the room and the participant received all further instructions via the computer screen. She was informed that *two* pieces of chocolates were hidden in the laboratory room and that her task was to search for them and find them as quickly as possible. She was further instructed to start and end the task by pressing a corresponding key on the computer keyboard. What the participant did not know was that actually only *one* piece of chocolate was hidden. The participant could abort searching for the second piece of chocolate by herself (by pressing the assigned computer key) or the search task was automatically aborted by a time-out after 7 min. The time passed until the participant quitted searching for the second piece by herself or automatically after 7 min, whatever came first, was recorded as a measure of motivation to search for chocolate. Search time was recorded in ms and transformed to minutes for further analysis.

1.2.4. Chocolate intake

At the end of the search, the experimenter feigned surprise about having forgotten to hide a second piece of chocolate and offered, as excuse, a chocolate gift, which was that the participant could take as many chocolate pieces as she wanted from a large bowl filled with chocolate pieces. The test bowl was weighed before and after the participant had taken chocolate(s), to provide a measure of chocolate intake in grams.

1.2.5. Questionnaires

The participant reported her subjective hunger and craving on 100 mm visual analogue scales (VAS), which were "hidden" among three irrelevant questions about concentration and mood. To disguise the aim of our study and to avoid suspicion by participants prior to the attention modification task, the craving and hunger questions did not explicitly ask for craving (or hunger) for chocolate specifically, but for craving and hunger in general. At the end of the experiment, the participant also completed the Restraint Scale (RS; Herman & Polivy, 1980) as a measure of weight and dieting concerns, the Dutch Eating Behaviour Questionnaire (DEBQ; van Strien, Frijters, Bergers, & Defares, 1986), as a measure of external eating, emotional eating and restrained eating, and the Attitudes to Chocolate Questionnaire (ACQ; Benton, Greenfield, & Morgan, 1998), as a measure of chocolate eating and problematic chocolate craving.

1.2.6. Body mass index

The body mass index (BMI; kg/m^2) was calculated by measuring the weight and height of each participant at the end of the experiment.

1.3. Procedure

Prior to testing, participants received a reminder e-mail in which they were asked to refrain from eating for two hours before coming to the laboratory. All participants were tested between 11 am and 5 pm. Participants were randomly allocated to one of the two experimental groups and all were tested individually in a dimly lit laboratory room. All participants provided informed consent before taking part in the study. Upon arrival, the participant filled in the baseline measure of craving and hunger. Then her dominant eye was determined and after a 9-point calibration and validation procedure, she started with the practice task and proceeded with her respective attention modification condition. The antisaccade task took approximately 35 min to complete. Immediately after the attention modification task, craving and hunger were assessed again. Then the bogus chocolate-search test was conducted and chocolate intake was assessed. Subsequently, all participants were asked to write down what they thought the purpose of this study was (to probe for suspicion) before filling in the Restraint Scale, DEBQ and the ACQ, before her height and weight were measured. The participant was thanked for her participation and compensated with a course credit or 7.50 Euro gift voucher.

1.4. Data reduction

Eye movements were recorded with an EyeLink 1000 system (SR Research Ltd., Mississauga, Ontario, Canada), with a temporal resolution of 1.4 ms and a spatial resolution of 0.01°. During data acquisition the eye tracker was automatically recalibrated whenever the fixation fell outside 3.64° × 3.40° of the fixation point. For data analysis purposes, trials were discarded when saccades were undershoots (i.e., saccades with an amplitude < 2°, see Nummenmaa, Hietanen, Calvo, & Hyona, 2011), or anticipatory saccades (i.e., saccades that occurred less than 80 ms after target presentation, see Bannerman, Milders, & Sahraie, 2010; Taylor & Hutton, 2009). Based on previous research (e.g., Unsworth, Schrock, & Engle, 2004; Wieser, Pauli, & Muhlberger, 2009), primary saccades were analysed, and the first saccade in each trial was categorized as an error or as a correct saccade based on its endpoint. For this purpose the computer screen was (hidden from participants), sub-divided into three basic areas: a mid-section (subtending at 7.06° × 8.66°), in which the fixation point was presented, the far left and the far right side of the screen (subtending at 33.62° × 10.26°, respectively), representing the regions of the screen surrounding the target (on pro-saccadic trials) or the mirror position of the target (on anti-saccadic trials). Based on these inclusion criteria, on average approximately 1.1% of data (SD = 1.48) was omitted per participant.

Data from five participants were removed completely because of recording failure during practice ($n = 1$) or because they had outlying high rates of missing data (>3 SD) during the practice trials ($n = 3$) or during the attention modification task ($n = 1$). Data of the remaining 51 participants were included in the analyse.[1]

[1] We conducted a sensitivity analysis that included these outliers and results remained the same.

Table 1
Main sample characteristics for participants in the "attend shoes" and in the "attend chocolate" training conditions, respectively.

	"Attend shoes" ($n = 26$)		"Attend chocolate" ($n = 25$)		$t(49)$	p
	M	SD	*M*	SD		
Age	19.50	1.82	19.28	1.93	0.42	.68
BMI	22.01	3.60	22.24	2.53	0.27	.79
Craving at baseline	50.58	29.46	48.28	24.89	0.30	.77
Hunger at baseline	51.42	28.78	44.20	26.06	0.94	.35
RS score	12.85	6.40	12.52	6.16	0.19	.85
Chocolate craving (ACQ)	31.39	14.31	34.16	20.89	0.54[a]	.59
Restrained eating (DEBQ)	3.02	0.96	2.93	0.73	0.39[a]	.70
Emotional eating (DEBQ)	2.40	0.74	2.51	0.54	0.59[b]	.56
External eating(DEBQ)	3.10	0.63	3.43	0.56	1.97[b]	.054

Note. Chocolate craving ACQ = Chocolate craving subscale of the Attitudes to Chocolate Questionnaire (Benton et al., 1998), DEBQ = Dutch Eating Behaviour Questionnaire (van Strien et al., 1986).
[a] Based on $df = 47$, because two participants did not fill in all questions.
[b] Based on $df = 48$, because one participant did not fill in all questions.

2. Results

2.1. Differences at baseline

There were no significant differences between experimental groups on any eating behaviour characteristics, such as restrained eating, chronic chocolate craving or BMI, or on their craving or hunger reports at baseline. Yet, there was a trend for participants in the "attend chocolate" group to express higher levels of external eating.[2] Descriptive statistics are shown in Table 1.

2.2. Eye-movements

Eye-tracking was integrated in this study with the aim to monitor how accurately participants followed their respective modification instructions, as possible moderator of effects. Overall, participants made correct saccades 82.32% (SD = 7.59) of trials during the attention modification task. Independent samples *t*-tests further confirmed that accuracy did not differ between experimental groups, $t(49) = 0.92$, $p = .36$.

To check for the possibility that underlying participants' characteristics affected the ability to comply with the modification instructions (i.e., accuracy), additional correlation analyses were performed. Accuracy was not related to individual characteristics such as BMI, eating characteristics (restrained eating, the three DEBQ measures of eating behaviour, trait chocolate craving), craving or hunger, all $rs < -.22$, all $ps > .11$.

Another aim of the eye-tracking was to test if the attention modification was successful in producing differences in attention for chocolate. For this aim the dwell time on chocolate was calculated and compared between conditions by means of an independent sample *t*-test. Overall, participants differed in their dwell time on chocolate stimuli during chocolate trials, in their respective condition, $t(51) = 43.42$, $p < .001$. Participants in the attend-chocolate condition focussed significantly longer on chocolate cues (82.46% of total trial time) than participants in the attend-shoe condition (6.95% of total trial time). Thus, the attention modification task yielded significant differences in attention for chocolate between conditions.

[2] The main analyses were repeated with external eating (centred) as a covariate. Results remained the same. The reported analyses do not include external eating as a covariate.

2.3. Attention modification effects on chocolate consumption, chocolate search time, craving and hunger

At first, independent samples *t*-tests were performed to test whether groups differed with respect to their chocolate intake or their search time. Chocolate intake was first logarithmically transformed because this variable was significantly positively skewed and therefore not normally distributed. Results revealed no effect of condition on chocolate intake, $t(49) = 0.05$, $p = .96$ or on search time $t(49) = 0.31$, $p = .76$, see Table 2. Similarly, independent *t*-tests on changes in craving and hunger (both variables were entered as difference scores from pre to post attention modification) due to the experimental attention modification condition showed no significant effects of the modification, $t(49) = 0.47$, $p = .64$ for differences in craving and $t(49) = 0.03$, $p = .97$ for differences in hunger, see Table 2.

In a next step we tested whether accuracy (i.e., overall percentage of correctly performed trials) moderated the effect of the experimental attention modification task on our outcome measures. We conducted a hierarchical linear regression analysis on logarithmically transformed chocolate intake with the experimental group (as dummy variable) and accuracy (centred) in step 1 and the interaction term of both variables entered in step 2. In Step 1, this regression model showed that condition and accuracy did not predict chocolate consumption. However, in Step 2 of the model there was a significant interaction of accuracy and experimental condition on chocolate intake ($p = .017$). Exact statistics are displayed in Table 3.

As can be seen by means of simple slope testing, plotted in Fig. 2, participants with higher accuracy (+1 SD) tended to eat more chocolate when their attention was modified towards chocolate stimuli and ate less chocolate when their attention was modified towards shoe stimuli, $\beta = .35$, $t(47) = 1.80$, $p = .078$ (two-tailed). The reversed pattern was seen for participants with lower accuracy (−1 SD): participants who were trained to attend to shoes tended to eat more chocolate than participants whose attention was modified to attend to chocolate, $\beta = -.34$, $t(47) = 1.72$, $p = .091$ (two-tailed).

To further analyse this interaction effect, we probed the effects of accuracy on chocolate intake within each condition ("attend shoe" or "attend chocolate"). Results revealed a trend, in that participants with lower accuracy differed from participants with higher accuracy regarding their chocolate intake in the attend shoe condition, $\beta = -.34$, $t(47) = 1.80$, $p = .079$ (two-tailed), and in the attend-chocolate condition, $\beta = .35$, $t(47) = 1.71$, $p = .094$ (two-tailed).

Table 2
Differences in chocolate consumption, search time for chocolates, and changes in craving and hunger from pre- to post modification, in the "attend shoes" and the "attend chocolate" attention modification conditions, respectively.

	Attend shoes ($n = 26$)	Attend chocolate ($n = 25$)	$t(49)$	p
	Mean (SD)	Mean (SD)		
Chocolate consumption	8.94 (12.23)	9.26 (15.41)	0.05	.96
Search time for chocolates	3.81 (2.25)	3.61 (2.49)	0.31	.76
Changes in craving	6.85 (14.40)	4.10 (26.32)	0.47	.64
Changes in hunger	5.54 (14.01)	5.72 (24.95)	0.03	.97

Note. Chocolate consumption is indicated in grams (but statistics are based on log-transformed chocolate consumption), search time is indicated in minutes searched for hidden chocolates, changes in craving indexes the differences from self-reported craving at baseline to self-reported craving after the attention modification task, changes in hunger refer to the difference from self-reported hunger at baseline to self-reported hunger after the attention modification task.

Table 3
Summary of the hierarchical linear regression model of variables predicting chocolate consumption.

Variable	*B*	SEB	*β*	*p*
Step 1				
1. Condition	.010	.157	.010	.948
2. Accuracy (%)	−.002	.010	−.022	.883
Step 2				
1. Condition	.006	.149	.005	.969
2. Accuracy (%)	−.024	.014	−.339	.079
3. Condition × Accuracy (%)	.049	.020	.466	.017

Note. R^2 for Step 1 = .001 (p = n.s.); ΔR^2 for Step 2 = .12 ($p = .017$).

To understand the meaning of higher and lower accuracy on the effect of the attention modification, we first examined the percentage of accuracy (i.e., rate of correctly performed pro − and anti-saccadic trials) in participants with higher and in participants with lower accuracy. Participants with higher accuracy (+1 SD) had a mean of 89.90% of correctly performed trials and participants with lower accuracy (−1 SD) had a mean of 74.79% correctly performed trials during the attention modification. To further explore the relation of accuracy and attention modification on chocolate consumption, an additional regression analysis was conducted testing if these differences in accuracy and their impact on chocolate intake could be explained by differences in attention for chocolate. For this aim, a hierarchical regression analysis for dwell time on chocolate as dependent variable was performed with accuracy (centred) and condition (as dummy variable), both entered in Step 1, and the interaction term of these variables, entered in Step 2, as independent predictors. In Step 1, this regression model showed a significant main effect of condition on the time participants dwelled on chocolate images during the attention modification task, as was previously shown in an independent t-test. In addition, in Step 2 of the model there was a significant interaction of accuracy and experimental condition on dwell time on chocolate ($p = .007$). Yet, adding the accuracy × condition interaction to the model was only associated with a minimal increase in total explained variance (ΔR^2 for Step 2 = .003; Table 4). Simple slopes, as displayed in Fig. 3, showed that the effect of condition on dwell time for chocolate was overwhelmingly large, for both higher (+1 SD) and lower accuracy (−1 SD), $ts > 30.80$, $ps < .001$. The results of this post-hoc analysis suggest that moderating effects of accuracy during the task on

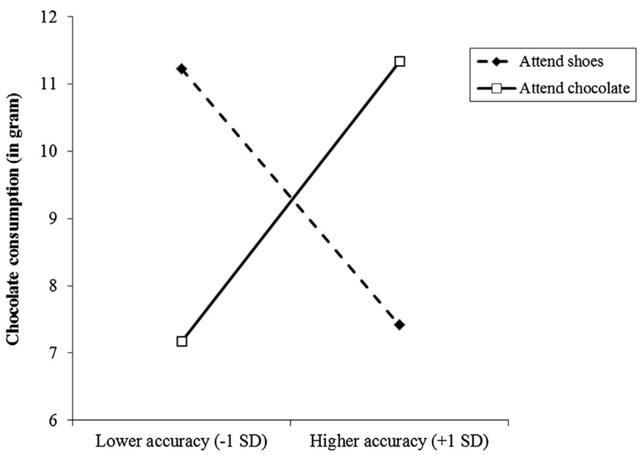

Fig. 2. Chocolate consumption (in gram) as a function of higher (+1 SD) and lower (−1 SD) accuracy for the "attend shoe" and the "attend chocolate" condition, respectively.

Table 4
Summary of the hierarchical linear regression model of variables predicting dwell time on chocolate (as percentage score of mean total dwell time per trial).

Variable	*B*	SEB	*β*	*p*
Step 1				
1. Condition	75.87	1.73	.99	.000
2. Accuracy (%)	−0.18	0.12	−.036	.119
Step 2				
1. Condition	75.81	1.61	.991	.000
2. Accuracy (%)	−0.46	0.15	−.091	.003
3. Condition × Accuracy (%)	0.61	0.22	.081	.007

Note. R^2 for Step 1 = .976 ($p < .001$); ΔR^2 for Step 2 = .003 ($p = .007$).

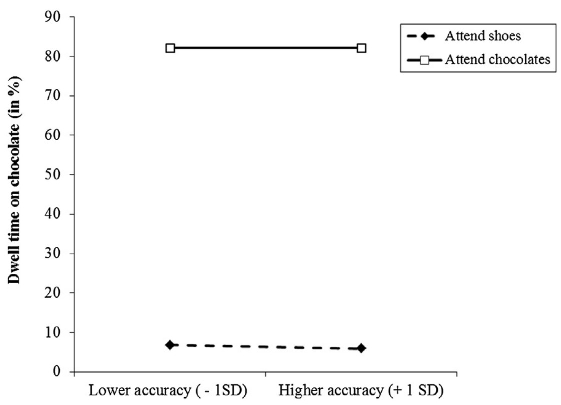

Fig. 3. Mean percentage of dwell time on chocolate during chocolate trials as a function of higher (+1 SD) and lower (−1 SD) accuracy for the "attend shoe" and the "attend chocolate" condition, respectively.

chocolate intake are unlikely to be explained by differences in attention for chocolate.

To test whether search time for hidden chocolate differed between conditions, we conducted another hierarchical linear regression analysis with the experimental condition (as dummy variable) and accuracy (centred) in step 1 and the interaction term of both variables entered in step 2. The regression analysis showed no significant main effects or interaction predicting search time (all βs < −.07, all *ts* < −.47, all *ps* > .65), indicating that the attention modification condition and/or accuracy did not affect search times for chocolates.

Third, to test whether accuracy moderated the effect of the experimental attention modification condition on changes in craving or hunger, two hierarchical linear regression analyses for differences in craving or hunger as dependent variables (computed as differences between pre and post indication of craving and hunger on the VAS scales) were performed. In Step 1, the experimental condition (as dummy variable) and accuracy (centred) was entered, and the interaction term of both variables was entered in step 2. In both analyses, no significant effects of experimental attention modification condition and/or accuracy were found on changes in craving or hunger, all βs < .09, all *ts* < 0.52, all *ps* > .61 for differences in craving; all βs < .27, all *ts* < 1.37, all *ps* > .18 for differences in hunger.

3. Discussion

The aim of the present study was to investigate the influence of attention for chocolate on chocolate consumption in the laboratory. In line with our hypothesis, the current results suggest that modifying attention for chocolate cues affects chocolate consumption, yet the accuracy of saccadic eye-movements according to the task instructions had a moderating influence on this effect. Our results showed that participants with higher accuracy ate more chocolate when they had to attend to chocolate and ate less chocolate when they had to attend to non-food stimuli. Exactly the reverse was found for participants with lower accuracy. At the moment, we can only speculate on what might have caused differences in accuracy. In this respect it is noteworthy that we did not find a significant association of eating related variables (such as BMI, restrained eating or chronic chocolate craving) and accuracy. This means that differences in accuracy are probably not the result of differences in BMI status, chronic chocolate craving or restrained eating behaviour. Yet, it is possible that an underlying attention bias for chocolate or differences in executive or impulse control might have contributed to differences in attention modification accuracy and chocolate consumption. Note that the experimental attention modification and/or accuracy had no effect, however, on craving or search time for chocolates.

Moreover, results regarding chocolate intake should be interpreted cautiously because the present study compared the effects of two manipulations with each other, which makes it difficult to determine whether the observed effect on intake was actually driven by an increase in consumption in the "attend chocolate" condition or by a decrease of consumption in the "attend shoes" condition.

Even though the aim of this study was finding a proof for the hypothesized relation of attention for food and food intake and applied for this aim an attention modification task, this novel paradigm could be interesting in terms of an application in a more clinical study or setting. In general, the ABM task in the present study differed from previous ABM training procedures in two respects: first, the current task modified visual attention directly. In the typically used visual probe task, participants need to look at both stimuli in each trial to evaluate where to direct their attention. In contrast, a particular strength of the current task is that participants are required to voluntarily control their saccadic eye movements and therefore actively avoid or approach one or the other category of task stimuli. In comparison to former ABM procedures that manipulated attention processes through training of manual response latencies, this novel approach might be more effective because visual attention is trained directly. For example, another current study (Hardman, Rogers, Etchells, Houstoun, & Munafò, 2013) that tried to manipulate attention biases for food by means of the response-latency-based visual probe task failed to produce significant changes in food intake. Second, another advantage of this novel approach to modify attention in the current study was the recording of eye-movements during the task. The recordings of eye movements enabled us to account for the participant's compliance with the task instructions (i.e., accuracy).

Besides, it is also possible that the applied anti-saccade task is more ecologically valid in comparison to the visual probe task with response latency measurements, because the visual attention allocation participants have to perform during this modification task might mirror how participants would decide how to (dis) engage attention to food cues in their natural environment: data from a pilot study suggested that participants were able to recognize the stimuli peripherally, even when they had to look away from them. However, future research should test whether the current attention modification procedure was successful in inducing a longer-lasting attentional bias for food cues, for example by testing how participants perform in a subsequent attention paradigm. Moreover, it could also be interesting for future research to determine how attention modification for food cues relates to experimental trainings that are addressing implicit processes with the aim to reduce food intake (e.g., inhibition training, see e.g., Houben and Jansen (2011))

The findings of the present study contrast somewhat with Smith and Rieger (2009), who found that participants who were manipulated to attend high caloric food words choose more often low caloric over high caloric cookies, after a body image challenge, in comparison to participants who attended neutral words. The aim of the present study diverged from the aim of the study by Smith and Rieger (2009) who focussed on (general) food choice. Moreover, the body image challenge as used by Smith and Rieger (2009) might have activated dieting goals, thereby possibly contributing to an increase in caloric-conscious food decisions afterwards (Anschutz, Van Strien, & Engels, 2011; Papies & Hamstra, 2010). In contrast, in our study no body image measures were included and we also decided to measure eating behaviour characteristics after the taste test to avoid inducing any dieting or restraint association (Papies & Hamstra, 2010), which might have counteracted or influenced the pure effects of the ABM training. In this respect, it could be interesting for future studies to examine whether ABM influences both the amount of food consumed and food choice.

Whereas the preliminary evidence of the applied attention modification for chocolate intake seems promising for future attention modification trainings it is notable that the ABM procedure did not affect the amount of time that participants searched for chocolate nor did attention for chocolate affect craving for chocolate or subjective hunger. A likely explanation for this lack of an effect regarding search time could be that this search task might not accurately assess chocolate motivation. One explanation for the lack of an effect on craving could be that participants were asked to indicate their craving for food in general and not specifically for chocolate. Research has shown that food cravings are specifically related to the kind of food consumed (Martin, O'Neil, Tollefson, Greenway, & White, 2008). Therefore, future studies should test the effects of attention modification on craving with more specific measures. In line with this, studies exploring ABM for appetitive stimuli in addiction research have reported inconsistent findings regarding the effects of ABM on craving (e.g., Attwood, O'Sullivan, Leonards, Mackintosh, & Munafò, 2008; Field et al., 2007; Field, Duka, Tyler, & Schoenmakers, 2009; Field & Eastwood, 2005; Schoenmakers, Wiers, Jones, Bruce, & Jansen, 2007). Moreover, previous research in the field of addiction research indicated that the extent to which participants are aware of the training contingencies can influence their behaviour. For example, Attwood et al. (2008) and Field et al. (2007) observed ABM effects only in contingency-aware participants. In the present study, we did not assess contingency awareness of participants explicitly but only probed for suspicion. None of the participants indicated that she knew that chocolate consumption was measured, and therefore it seems unlikely that participants ate more or less chocolate because they were aware of the modification contingencies. Yet, future studies should consider measuring contingency awareness. Another important point to note, when interpreting the current findings is that our results apply to a specific food item: chocolate. It would be interesting to determine whether the current findings generalize from ABM for chocolate stimuli to other high-caloric food stimuli or whether ABM for a certain food condition generalizes to other types of food. In this respect, it might be interesting for future studies to investigate the impact using a similar attention modification procedure contrasting high calorie, palatable food with low calorie food stimuli on subsequent food consumption, as this would be most similar with food exposure in our real food environment.

In conclusion, the results showed that attention bias modification towards and away from chocolate stimuli was related to the amount of chocolate consumption, but only when attention modification was accurately, thereby providing preliminary evidence for an influence of attention for food on subsequent food intake, which might not necessarily be mediated by (conscious) changes in craving. Yet, the issue of causality remains because accuracy in the attention modification task interacted with the effect of modified attention on chocolate versus shoes on subsequent chocolate intake in the current study.

The results of an additional post-hoc analysis suggest that the moderating effect of accuracy on chocolate consumption is not driven by differences in dwell-time on chocolate. That is, dwell-time on chocolate versus shoes was almost completely determined by the modification condition, and hardly depended on the accuracy. This suggests that another (unmeasured) characteristic of the high versus the low accuracy performers determines whether the attention modification either works or does not work for them with regard to their chocolate intake.

Nevertheless, the current finding suggests important theoretical implications for the role of attention on food intake, in that paying attention to food could form a risk for weight gain, particularly when living in an obesogenic food environment. In this respect, knowledge about the working mechanisms of attention and food consumption could have potential clinical benefits. Future research should therefore aim to extend the current findings, thereby further clarifying whether attention modification can impact food intake in general and examining the stability of effects.

Role of funding sources

Jessica Werthmann is funded by a PhD fellowship from Maastricht University. The funding source had no role in the study design, the collection, analysis or interpretation of the data.

Conflict of interest

None.

References

Anschutz, D. J., Van Strien, T., & Engels, R. C. M. E. (2011). Exposure to slim images in mass media: television commercials as reminders of restriction in restrained eaters. *Psychology of Popular Media Culture, 1*(S), 48–59. http://dx.doi.org/10.1037/2160-4134.1.s.48.

Attwood, A. S., O'Sullivan, H., Leonards, U., Mackintosh, B., & Munafò, M. R. (2008). Attentional bias training and cue reactivity in cigarette smokers. *Addiction, 103*(11), 1875–1882. http://dx.doi.org/10.1111/j.1360-0443.2008.02335.x.

Bannerman, R. L., Milders, M., de Gelder, B., & Sahraie, A. (2009). Orienting to threat: faster localization of fearful facial expressions and body postures revealed by saccadic eye movements, Proceedings of the Royal Sociaty B: Biological Sciences. *276*(1662), 1635–1641.

Bannerman, R. L., Milders, M., & Sahraie, A. (2010). Attentional bias to brief threat-related faces revealed by saccadic eye movements. *Emotion, 10*(5), 733–738.

Bar-Haim, Y. (2010). Research review: attention bias modification (ABM): a novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry, 51*(8), 859–870. http://dx.doi.org/10.1111/j.1469-7610.2010.02251.x.

Bar-Haim, Y., Morag, I., & Glickman, S. (2011). Training anxious children to disengage attention from threat: a randomized controlled trial. *Journal of Child Psychology and Psychiatry, 52*(8), 861–869. http://dx.doi.org/10.1111/j.1469-7610.2011.02368.x.

Benton, D., Greenfield, K., & Morgan, M. (1998). The development of the attitudes to chocolate questionnaire. *Personality and Individual Differences, 24*(4), 513–520. http://dx.doi.org/10.1016/s0191-8869(97)00215-8.

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. [Article]. *International Journal of Obesity, 33*(9), 1063–1073. http://dx.doi.org/10.1038/ijo.2009.138.

Field, M., Duka, T., Eastwood, B., Child, R., Santarcangelo, M., & Gayton, M. (2007). Experimental manipulation of attentional biases in heavy drinkers: do the effects generalise? *Psychopharmacology, 192*(4), 593–608. http://dx.doi.org/10.1007/s00213-007-0760-9.

Field, M., Duka, T., Tyler, E., & Schoenmakers, T. (2009). Attentional bias modification in tobacco smokers. *Nicotine & Tobacco Research, 11*(7), 812–822. http://dx.doi.org/10.1093/ntr/ntp067.

Field, M., & Eastwood, B. (2005). Experimental manipulation of attentional bias increases the motivation to drink alcohol. *Psychopharmacology, 183*(3), 350–357. http://dx.doi.org/10.1007/s00213-005-0202-5.

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., et al. (2010). Attention bias modification treatment: a meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry, 68*(11), 982–990. http://dx.doi.org/10.1016/j.biopsych.2010.07.021.

Hallett, P. E. (1978). Primary and secondary saccades to goals defined by instructions. *Vision Research, 18*(10), 1279–1296. http://dx.doi.org/10.1016/0042-6989(78)90218-3.

Hallett, P. E., & Adams, B. D. (1980). The predictability of saccadic latency in a novel voluntary oculomotor task. *Vision Research, 20*(4), 329–339. http://dx.doi.org/10.1016/0042-6989(80)90019-x.

Hallion, L. S., & Ruscio, A. M. (2011). A meta-analysis of the effect of cognitive bias modification on anxiety and depression. *Psychological Bulletin, 137*(6), 940–958. http://dx.doi.org/10.1037/a0024355.

Hardman, C. A., Rogers, P. J., Etchells, K. A., Houstoun, K. V. E., & Munafò, M. R. (2013). The effects of food-related attentional bias training on appetite and food intake. *Appetite, 71*(0), 295–300. http://dx.doi.org/10.1016/j.appet.2013.08.021.

Herman, C. P., & Polivy, J. (1980). Restrained eating. In A. J. Stunkard (Ed.), *Obesity* (pp. 209–224). Philadelphia: Saunders.

Hetherington, M. M., & Macdiarmid, J. I. (1993). 'Chocolate addiction': a preliminary study of its description and its relationship to problem eating. *Appetite, 21*(3), 233–246. http://dx.doi.org/10.1006/appe.1993.1042.

Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite, 56*(2), 345–349.

Hutton, S. B. (2008). Cognitive control of saccadic eye movements. *Brain and Cognition, 68*(3), 327–340. http://dx.doi.org/10.1016/j.bandc.2008.08.021.

Keatley, D., Clarke, D. D., & Hagger, M. S. (2012). Investigating the predictive validity of implicit and explicit measures of motivation in problem-solving behavioural tasks. *British Journal of Social Psychology, 28*(10), 2044–8309.

Kemps, E., & Tiggemann, M. (2009). Attentional bias for craving-related (chocolate) food cues. *Experimental and Clinical Psychopharmacology, 17*(6), 425–433. http://dx.doi.org/10.1037/a0017796.

Kissler, J., & Keil, A. (2008). Look-don't look! How emotional pictures affect pro- and anti-saccades. *Exp Brain Res, 188*(2), 215–222.

Martin, C. K., O'Neil, P. M., Tollefson, G., Greenway, F. L., & White, M. A. (2008). The association between food cravings and consumption of specific foods in a laboratory taste test. *Appetite, 51*(2), 324–326. http://dx.doi.org/10.1016/j.appet.2008.03.002.

Mathews, A., & MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cognition and Emotion, 16*(3), 331–354.

Miller, A., & Hom, H. L. (1990). Influence of extrinsic and ego incentive value on persistence after failure and continuing motivation. *Journal of Educational Psychology, 82*(3), 539–545. http://dx.doi.org/10.1037/0022-0663.82.3.539.

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*(2), 227–237. http://dx.doi.org/10.1016/S0005-7967(97)00062-4.

Munoz, D. P., & Everling, S. (2004). Look away: the anti-saccade task and the voluntary control of eye movement. *Nature Reviews Neuroscience, 5*(3), 218–228. http://dx.doi.org/10.1038/nrn1345.

Murdaugh, D. L., Cox, J. E., Cook, E. W., III., & Weller, R. E. (2012). fMRI reactivity to high-calorie food pictures predicts short- and long-term outcome in a weight-loss program. *NeuroImage, 59*(3), 2709–2721. http://dx.doi.org/10.1016/j.neuroimage.2011.10.071.

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2010). Food-related Stroop interference in obese and normal-weight individuals: behavioral and electrophysiological indices. *Eating Behaviors, 11*(4), 258–265. http://dx.doi.org/10.1016/j.eatbeh.2010.07.002.

Nijs, I. M. T., Muris, P., Euser, A. S., & Franken, I. H. A. (2010). Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite, 54*(2), 243–254. http://dx.doi.org/10.1016/j.appet.2009.11.004.

Nummenmaa, L., Hietanen, J. K., Calvo, M. G., & Hyona, J. (2011). Food catches the eye but not for everyone: a BMI-contingent attentional bias in rapid detection of nutriments. *PLoS One, 6*(5), 16.

Papies, E. K., & Hamstra, P. (2010). Goal priming and eating behavior: enhancing self-regulation by environmental cues. *Health Psychology, 29*(4), 384–388. http://dx.doi.org/10.1037/a0019877.

Piech, R. M., Pastorino, M. T., & Zald, D. H. (2010). All I saw was the cake. Hunger effects on attentional capture by visual food cues. *Appetite, 54*(3), 579–582. http://dx.doi.org/10.1016/j.appet.2009.11.003.

Schoenmakers, T., Wiers, R. W., Jones, B. T., Bruce, G., & Jansen, A. T. M. (2007). Attentional re-training decreases attentional bias in heavy drinkers without generalization. *Addiction, 102*(3), 399–405. http://dx.doi.org/10.1111/j.1360-0443.2006.01718.x.

Smeets, E., Roefs, A., & Jansen, A. (2009). Experimentally induced chocolate craving leads to an attentional bias in increased distraction but not in speeded detection. *Appetite, 53*(3), 370–375. http://dx.doi.org/10.1016/j.appet.2009.07.020.

Smith, E., & Rieger, E. (2009). The effect of attentional training on body dissatisfaction and dietary restriction. *European Eating Disorders Review, 17*(3), 169–176. http://dx.doi.org/10.1002/erv.921.

Stice, E., Yokum, S., Bohon, C., Marti, N., & Smolen, A. (2010). Reward circuitry responsivity to food predicts future increases in body mass: moderating effects of DRD2 and DRD4. *NeuroImage, 50*(4), 1618–1625. http://dx.doi.org/10.1016/j.neuroimage.2010.01.081.

van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch eating behavior questionnaire (DEBQ) for assessment of restrained emotional, and external eating behavior. *International Journal of Eating Disorders, 5*(2), 295–315. http://dx.doi.org/10.1002/1098-108X(198602)5:2<295::AID-EAT2260050209>3.0.CO;2-T.

Taylor, A. J., & Hutton, S. B. (2009). The effects of task instructions on pro and antisaccade performance. *Experimental Brain Research, 195*(1), 5–14.

Unsworth, N., Schrock, J. C., & Engle, R. W. (2004). Working memory capacity and the antisaccade task: individual differences in voluntary saccade control. *Journal of Experimental Psychology: Learning, Memory and Cognition, 30*(6), 1302–1321.

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. http://dx.doi.org/10.1037/a0024291.

Wieser, M. J., Pauli, P., & Muhlberger, A. (2009). Probing the attentional control theory in social anxiety: an emotional saccade task. *Cognitive, Affective, & Behavioral Neuroscience, 9*(3), 314–322.

Yokum, S., Ng, J., & Stice, E. (2011). Attentional bias to food images associated with elevated weight and future weight gain: an fMRI study. *Obesity, 19*(9), 1775–1783. http://dx.doi.org/10.1038/oby.2011.168.