## Conference on 'Changing dietary behaviour: physiology through to practice' Symposium 1: Novel imaging and other methodologies for assessing health and behaviour: applications for nutrition

# Worry or craving? A selective review of evidence for food-related attention biases in obese individuals, eating-disorder patients, restrained eaters and healthy samples

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Living in an 'obesogenic' environment poses a serious challenge for weight maintenance. However, many people are able to maintain a healthy weight indicating that not everybody is equally susceptible to the temptations of this food environment. The way in which someone perceives and reacts to food cues, that is, cognitive processes, could underlie differences in susceptibility. An attention bias for food could be such a cognitive factor that contributes to overeating. However, an attention bias for food has also been implicated with restrained eating and eating-disorder symptomatology. The primary aim of the present review was to determine whether an attention bias for food is specifically related to obesity while also reviewing evidence for attention biases in eating-disorder patients, restrained eaters and healthy-weight individuals. Another aim was to systematically examine how selective attention for food relates (causally) to eating behaviour. Current empirical evidence on attention bias for food within obese samples, eating-disorder patients, and, even though to a lesser extent, in restrained eaters is contradictory. However, present experimental studies provide relatively consistent evidence that an attention bias for food contributes to subsequent food intake. This review highlights the need to distinguish not only between different (temporal) attention bias components, but also to take different motivations (craving *v.* worry) and their impact on attentional processing into account. Overall, the current state of research suggests that biased attention could be one important cognitive mechanism by which the food environment tempts us into overeating.

**Attention bias: Obesity: Craving: Restrained eating: Eating disorder**

### Surrounded by an 'obesogenic' food environment?

Obesity and overweight constitute a serious risk for psychological and physical wellbeing[1–8]. The WHO estimates that 2·8 million people die each year due to the adverse consequences of overweight and obesity[7,8]. Ultimately, obesity is caused by a long-lasting imbalance of energy intake and energy expenditure. This imbalance is mainly caused by excessive food intake[9,10]. Our 'obesogenic' food environment is characterised by an abundance of palatable, high-energy, cheap and convenient food that is constantly available and promoted aggressively[11,12]. Living in such an environment poses a serious challenge for maintaining a healthy weight. However, the majority of individuals have a healthy weight suggesting that not everybody is equally susceptible to the temptations of this obesogenic food environment. What explains these apparent individual differences in susceptibility? One hypothesis is that certain people find high-energy food more attractive and that this increased 'hedonic hunger'[13] leads to craving and (over)eating thereby contributing to weight gain and obesity. Cognitive processes (i.e. the way in which someone processes and perceives food temptations),

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could reflect and contribute to individual differences in the susceptibility to food temptations. An attention bias for food could be one important cognitive process in this respect.

A food-related attention bias refers to selective attentional processing of food cues, including both voluntary and involuntary processes. Food is essential for survival and especially high-energy food cues are potent in quickly capturing attention[14]. However, in an obesogenic environment, such a bias for food stimuli could be problematic, especially when trying to lose weight. A growing body of research is investigating if an attention bias for food is indeed related to eating behaviour and obesity. However, an attention bias for food has also been implicated in restrained eating (i.e. dieting intentions) and eating disorders (i.e. worry about food intake). Thus, a major question concerns the meaning of an attention bias for food, as it is unclear if an attention bias for food reflects craving and hedonic motivation for food or worry about food intake.

## Attention is biased by craving and by worry: two sides of the same coin?

According to addiction theories, an attention bias for desired (substance-related) cues is a major force in drug seeking and drug taking behaviour. According to the incentive sensitisation model by Berridge *et al.*[15–17], addictive cues signalling the imminent drug consumption gain incentive properties during a conditioning process of repeated signalling and subsequent drug consumption. As a result of this process, these stimuli become salient in the environment and are then potent to 'grab attention' of drug users. This model has been extended as an explanation for overeating in the context of obesity[18]: through a conditioning process based on the rewarding effects of food intake, cues (such as the sight of food) can gain incentive salience and thus become potent to attract attention. It has further been posited that attention bias for food cues and craving stand in a reciprocal relationship: biased attention for food cues is thought to evoke food cravings, whereas the opposite is also possible: craving for food steers attention bias for food cues[19,20]. Thus, according to this addiction account of overeating, obesity should be associated with increased attentional biases towards food reflecting motivational approach for eating.

However, theoretically, it is also possible that eating-related worries or dieting intentions are associated with an attention bias for food cues. According to a cognitive-behavioural account of eating disorders, an attentional bias for food reflects fear of gaining weight or losing control over eating[21,22]. Schemas related to body size and shape concerns can be activated by external or internal cues. These schemas then bias the individual's attention for food. Hence, in the context of weight concerns, an attention bias for food could contribute to dietary restraint and (behavioural) avoidance of food stimuli[21,23]. Considering that an obese person undertakes many dieting attempts[24–26], and that obesity can be associated

with body concerns[27], it is possible that in the context of obesity an attention bias for food might reflect worry about food intake or concerns about weight and body shape. This implies that the interpretation of an attentional bias for food in obese individuals may not be so straightforward as sometimes is suggested. Thus, it is not immediately clear whether an observed attention bias reflects a craving for food or concerns regarding food intake or even both.

To answer this question, the aim of the present review was to critically summarise existing empirical studies to find out whether an attention bias for food reflects worry over food intake or appetitive motivation. For this aim, research findings on attention bias for food in overweight and obese and in healthy-weight participants, attention bias for food in eating-disorder samples and attention bias for food in restrained eaters have been reviewed.

Another important question is whether biased attention for food is more than the expression of motivational states (worry about intake or craving) and can causally influence eating behaviour. Thus, to determine whether biased attention is more than an epiphenomenon reflecting individual differences in craving and/or eating concerns, empirical evidence testing the causal impact of biased attention for food on subsequent eating behaviour was also reviewed.

## Assessment of visual attention for food: many roads lead to Rome?

Conceptualisations of attention bias and attentional components vary a lot in current research on food-related attention. In general, two attentional mechanisms can be distinguished: (1) attention prioritises relevant information and this selection mechanism can be involuntary (i.e. a bottom-up process, for example, when we see an ambulance); or (2) attention can be steered voluntarily (i.e. a top-down process, for example, when we search for a certain brand of pasta on the shelves in a supermarket). Early attention components are associated with more involuntary, less controlled mechanisms, whereas later attention components are thought to reflect the slower top-down mechanisms of voluntary or more controlled processing[28,29].

At least three different methodologies have been applied in previous studies to asses visual attentional biases for food: (1) measuring response latencies or the calculation of an interference effect during a food-Stroop task; (2) assessment of response latencies during a spatial attention paradigm, such as the visual probe task, the exogenous cueing task or the visual search task; (3) recordings of eye-movements during an attention paradigm.

Most research on food-related attention, especially in eating-disorder patients and restrained eaters, applied the food-Stroop task[30,31]. During this task, coloured food and non-food words are presented, and participants are required to indicate the colour of the word as quickly as possible, irrespective of the meaning of the word. The Stroop interference score is calculated by obtaining

a difference score between the average response latency on food v. non-food trials. This interference score should reflect biased attention. That is, an attentional bias for food stimuli is assumed if the response latency is relatively prolonged on food trials. A disadvantage of this paradigm is that it cannot inform on the underlying attentional processes. The slow-down in colour-naming could be caused both, by increased attention for the semantic meaning, or by avoidance of processing the stimulus word[32]. Moreover, it is unclear which attentional components are reflected in the interference effect: while it has been argued that the Stroop effect could reflect an early attentional process (i.e. involuntary semantic processing)[33], results of a meta-analysis suggested that it is more likely to reflect later attentional processes[34]. Taken together, a disadvantage of the food-Stroop task is that it is not clear which attentional component (early or later attentional processes) is captured, and that the interference effect cannot provide information on the direction (approach, thus increased attention towards food, v. avoidance, thus reduced attention for food) of attention.

The visual probe task[35] relies on the assessment of response latencies. During this task, two stimuli (a critical stimulus and a non-critical stimulus) are presented side by side on the computer screen for a fixed duration (typically 2000 ms). Then, both stimuli disappear, and a small probe appears in the position of one of the stimuli. Participants are instructed to press a corresponding key on the keyboard to indicate the location of the probe (e.g. left or right). The logic of this task presumes that participants react faster to indicate the position of the probe if their attention was already directed to the location (thus on the stimulus) in which the probe appears. An advantage of the visual probe is that it is possible to distinguish early and later attentional processes by including different presentation times: shorter stimulus presentations (100–500 ms) are thought to assess initial orientation, whereas longer stimulus presentations ($\geq$500 ms) are thought to assess maintained attention[36,37]. Moreover, the calculation of a response latency based attention bias allows for the interpretation of the direction of attention: the mean response latency in congruent trials (when the probe replaces the relevant picture) is subtracted from the mean response latency in incongruent trials (when the probe replaces the neutral stimulus). According to this calculation positive bias scores reflect attentional approach and negative bias scores suggest attentional avoidance[37].

The exogenous cueing paradigm relies on the same logic as the visual probe paradigm[38,39]. The only difference between these two paradigms is that in the exogenous cueing paradigm only one stimulus (without counterpart) is presented as cue per trial whereas in the visual probe task two stimuli are presented side by side. Similar to the visual probe task participants have to indicate the location of a probe following the cue (e.g. picture of a food item) as fast as possible.

During the visual search task[40], participants view search matrices depicting several stimuli, with either one presentation of a relevant stimulus among several irrelevant stimuli (measuring speeded detection) or the presentation of an irrelevant stimulus among several relevant stimuli (measuring increased distraction). Participants have to indicate the 'odd-one-out' stimulus as fast as possible. An attention bias is evidenced by: (a) speeded detection of the relevant among irrelevant stimuli (i.e. early attention) and/or (b) in increased distraction by relevant stimuli when searching for the irrelevant stimulus (i.e. later attention component). An advantage of this task is that these two attention components can be identified, and that an indication of the direction of attention (at least for increased attentional approach) can be provided. A disadvantage of this task is that the attentional component of increased distraction does not inform whether the assessed reaction time is due to the inability to shift attention away from the distracting stimuli or due to successive attentional attraction by the distracting stimuli[41].

In contrast to the indirect assessment of attention by measuring response latencies, visual attention can be measured directly through 'eye-tracking' by measuring eye-movements during the stimulus presentation. This technique can (partly) overcome the 'snap-shot' view that is obtained by an indirect assessment of attention, thereby providing a more sensitive measure for the temporal components and the direction of attention processing[42,43].

Owing to these methodological considerations, only those studies were reviewed that applied an attention paradigm that can inform on the temporal components of attention and/or can distinguish between attentional avoidance and approach processes based on recorded response latencies as an indirect measure of visual attention bias or on recorded eye-movements as a direct measure of visual attentional bias or on a combination of both. Eleven studies on attention bias for food in obese or overweight samples were reviewed. Five studies on attention bias for food in eating-disorder patients and nine studies on attentional bias for food in restrained eaters were included in this review. As another aim of the present review was to summarise research on the causal influence of attention bias for food on eating behaviour, five studies that manipulated an attention bias for food and measured subsequent food intake were also summarised.

## Attention bias for food and obesity

An overview of studies that examined food-related attention biases in relation to BMI and/or obesity is provided in Table 1. In line with an addiction account of food-related attention bias, some studies suggest that obese individuals, as compared with healthy-weight participants, showed an increased attentional approach bias to food cues. For example, obese participants initially oriented their attention more often towards food cues than towards non-food cues and maintained their gaze longer on food cues than did healthy-weight participants, when they were satiated[44]. Similarly, overweight and obese participants had a trend-significant increased attention bias for food (v. non-food) cues in comparison with healthy-weight

**Table 1.** Overview of evidence on attentional processing of food cues in obese, overweight and healthy weight samples (2009–2014)

| Reference | Sample | Paradigm | Measure | Attention components/ stimulus duration | Stimulus type | Stimulus content | Main findings |
|---|---|---|---|---|---|---|---|
| Castellanos et al.[44] | Eighteen OB (M BMI = 38·68), eighteen HW (M BMI = 21·73) | VP | EM, RT | Direction bias (EM) Duration bias (EM) 2000 ms (RT) | Picture pairs | HC food – non-food control, LC food – non-food control | When hungry: Direction bias: OB = HW[a] Duration bias OB = HW[a] RT: No effects When satiated: Direction bias: OB > HW Duration bias OB > HW RT: No effects |
| Pothos et al.[52] | 128 Mainly HW (M BMI = 22·74)† | VP‡, ST | RT | VP: 500, 1250 ms ST: Interference for healthy words Interference for unhealthy words | VP: Word pairs ST: Words | Healthy food – non-food control, Unhealthy food – non-food control | No significant correlation of BMI and RT |
| Calitri et al.[53]§ | 102 Mainly HW (M BMI time 1 = 23·32; M BMI time 2 = 23·64)‖ | VP‡, ST | RT | VP: 500, 1250 ms ST: Interference healthy words Interference unhealthy words | VP: Word pairs ST: Words | Healthy food – non-food control, Unhealthy food – non-food control | VP: no effects ST: r (Interference unhealthy words~BMI change) = −0·23[*] |
| Nijs et al.[19] | Twenty-six OW/OB (M BMI = 29·99), forty HW (M BMI = 20·63) | VP with RT¶, FV with EM, FV with ERP | VP with RT FV with EM FV with ERP | VP: 100 (RT), 500 ms (RT), FV: Direction bias (EM), Duration bias (EM), P300 bias (ERP) | Picture (pairs) | HC food – non-food control | Direction bias: HW = OW/OB[a] Duration bias: HW = OW/OB[a] When hungry: RT at 100 ms: OW/OB > HW, (trend)[a] P300 bias: HW > OW/OB, When satiated: P300 bias OW/OB > HW (trend) |
| Graham et al.[48] | Fifteen OW/OB (M BMI = 28·9[sr]), twenty-one HW†† (M BMI = 21·3[sr]) | FV | EM | Direction bias (EM) Duration bias (EM) Pupil diameter | Picture pairs | HC savoury food – LC food, HC savoury food – HC sweet food, HC sweet food – LC food, HC savoury food – HC savoury food, HC sweet food – HC sweet food, LC food – LC food | Direction bias (for low-energy food): OW/OB > HW Duration bias: No effects Pupil diameter: OW/OB: Decrease in diameter HC sweet food< HC savoury food |

| Study | Sample | Paradigm | Measure | Task | Stimuli | Food categories | Results |
|---|---|---|---|---|---|---|---|
| Nummenmaa et al.[47] | Study 1: twenty-seven HW Study 2: eighteen HW (M of both samples BMI = 21$^{sn}$)‡‡ | VS | RT (study 1), EM (study 2) | Study 1: RT to food v. control ('food detection advantage') 'Visual saliency scores' Study 2: RT 'decision time' EM 'latency of first fixation' EM 'dwell time' 'Visual saliency scores' | Picture matrix | Study 1: Palatable HC food, bland LC food, non-food control Study 2: Food (n.sp.) – non-food control | Study 1: *RT food detection advantage*: r (RT~BM) = −0·39* *Visual saliency*: No effects$^a$ Study 2: *RT 'decision time'*: r (RT~BMI) = −0·47* *EM*: r(EM 'latency of first fixation'~BMI) = −0·40* (one-tailed) *Visual saliency*: No effects *EM 'dwell time'*: No effects |
| Werthmann et al.[50] | Twenty-two OW/OB (M BMI = 28·03), twenty-nine HW (M BMI = 21·16) | VP | EM, RT | Direction bias (EM) Duration of initial fixation (EM) Duration bias (EM) 2000 ms (RT) | Picture pairs | HC food – non-food control | *Direction bias*: OW/OB > HW *Duration of initial fixation*: OW/OB < HW *Duration bias*: OW/OB = HW *RT*: OW/OB = HW |
| Gearhardt et al.[49] | 100 OW/OB (M BMI = 35·07) | VS | RT | RT 'vigilance' RT 'dwell time' | Picture matrix | Different food types were contrasted (e.g. type 1 = high added fat and high added sugar, type 6 = low natural sugar and low natural fat) | *RT vigilance*: BMI negatively predicted RT scores for 'fried food', F (1,89) = 2·10* |
| Nathan et al. 2[45] | Twenty-six OW/OB§§ (M BMI = 32·7) | ST, VP | RT | VP:‖ ‖ 500 ms 2000 ms; ST: Interference for palatable food words Interference for colour words | VP: Picture pairs ST: palatable food words, non-palatable food words, matched non-food words | VP: HC and LC energy food – non-food control ST: Palatable food, palatable food, non-food control | VP: *Low RS*: Food > Non-food (trend, one sample t test, placebo condition) *High RS*: No bias for food (one sample t tests) ST: *Low RS*: Interference for food words (one sample t test, placebo condition) *High RS*: No interference for food (one sample t tests) |
| Loeber et al.[51] | Twenty OW/OB (M BMI = 38.8), twenty HW (M BMI = 22·6)¶¶ | VP | RT | 50 ms | Picture pairs | Palatable, food-associated – non-food control | No effects: OB = HW |

Table 1. (Cont.)

| Reference | Sample | Paradigm | Measure | Attention components/stimulus duration | Stimulus type | Stimulus content | Main findings |
|---|---|---|---|---|---|---|---|
| Schmitz et al.[46] | Twenty-seven OW/OB BED (M = BMI 34·71), thirty-three OW/OB (M = BMI 32·41) | CT, EC | RT | CT: max. 7 s EC: 100 ms, engagement, disengagement | CT: Words EC: Pictures | Palatable, HC food – non-food control | CT: BED > OB EC: *Engagement:* BED > OB *Disengagement:* BED = OB[a] |

VP, visual probe task; ST, Stroop task; VS, Visual Search; FV, free viewing; CT, clarification task; EC, exogenous cueing task; EM, tracking of eye-movements; RT, response latencies; ERP, event-related potentials; HC, high-energy food cues; LC, low-energy food cues; OB, obese participants; OW, overweight participants; HW, healthy weight participants; RS, restrained eating; BED, binge-eating disorder patients; M, mean; n. sp., not specified; sr, self-report. [a] Note that a main effect for attention bias for food cues over non-food cues was reported. P < 0.05.
[†] Including 69 female and 59 male participants.
[‡] Two VP version were administered, one with 500 ms stimulus duration and one with 1250 ms stimulus duration time.
[§] Note that (parts of) the sample, methodology and data in Calitri et al.[53] is based on data collection of Pothos et al.[52].
[‖] Including 58 female and 44 male participants.
[¶] Half of the trials were presented with 100 ms presentation duration, and half of the trials were presented with 500 ms presentation duration.
[††] Including three underweight participants.
[‡‡] Including four male participants and eleven female participants.
[§§] Including fifteen male and eleven female participants.
[‖‖] Half of the trials were presented either with 500 or 2000 ms duration.
[¶¶] Including seven male and thirteen female participants per group.

participants ([19], recordings of response latencies to food cues at 100 ms). Correspondingly, obese participants, who did not restrain their food intake, preferentially attended food words in comparison with non-food words ([45], trend in one sample *t* tests within low restrained participants in the placebo condition; note that it has not been reported whether high restrained participants differed significantly from low restrained participants in their attention bias for food). Moreover, another study showed that both obese and obese binge-eating disorder patients were significantly slower to disengage from food cues than from non-food cues, whereas only obese binge-eating disorder patients showed increased engagement with food *v.* non-food cues[46].

In contrast, other research suggests that a higher BMI is associated with attentional avoidance of food. For example, Nummenmaa *et al.*[47] reported a negative association between initial orientation towards food cues and BMI, in a group of mainly healthy-weight participants. Another study showed that healthy-weight participants paid significantly less attention to low-energy than high-energy food compared with obese participants with dieting intentions[48]. This finding suggests that obese individuals who want to lose weight pay more attention to low-energy foods than healthy-weight individuals. Thus, weight groups differed only in their attention bias for low-energy food, but not for high-energy food cues. Similarly, within a sample of obese participants, higher BMI was found to be associated with less initial attention bias for fried foods[49]. Moreover, high restrained obese participants did not show an attention bias towards food ([45], one-sample *t* tests within highly restrained participants). Together, these results seem to suggest that a higher BMI is associated with attentional avoidance of palatable high-energy food, or with an increased attention focus on low-energy food.

One study seems to combine these contradictory findings, by reporting an approach-avoidance pattern of results[50]. This study found that obese and overweight participants showed increased attentional approach towards high-energy food pictures on an early measure of attention bias (i.e. direction bias) as compared to healthy-weight participants, under conditions of satiety. However, in a slightly later attention process (i.e. durations of initial fixations), obese participants showed attentional avoidance of high-fat food pictures. This finding might suggest an approach-avoidance process of attention processing that could reflect the inner conflict of obese or overweight participants, who might feel automatically attracted towards food, yet might also try to avoid looking at food in an attempt to down-regulate their craving for this food.

However, there are also several studies that did not find a significant relation of BMI and attentional processing of food cues (e.g. [51,52]). Moreover, one study explicitly tested that healthy *and* obese individuals alike paid significantly more attention to food pictures than to non-food pictures, independent of their hunger or satiety state ([19], see data on eye-tracking).

Evidence on the predictive validity of attention bias for food on changes in BMI is still rare. Only one

published study has so far tested if attention bias towards unhealthy or healthy food cues was associated with BMI change over 12 months, in a mostly healthy-weight student sample[53]. Results showed that food- Stroop interference for unhealthy food words was related to BMI increase after 1 year. However, an attention bias based on response latencies during the visual probe task was not related to weight change over time.

In summary, current evidence on attention bias for food cues in obese participants is very mixed, as there is empirical evidence for approach, avoidance and approach-avoidance attention processes in obese v. healthy-weight participants when viewing food cues. Moreover, it is questionable if obese participants do at all hold stronger attentional biases for food in comparison to healthy-weight participants, considering that some studies indicated no differences in attention allocation for food cues between healthy-weight and obese participants.

### Attention bias for food and eating disorders

Giel et al.[54] showed that anorexic patients as well as (8 h-fasted and 1 h-fasted) healthy-weight control participants all initially directed their attention more often towards food than non-food cues. However, healthy-weight participants maintained their gaze significantly longer on food than on non-food pictures in comparison to anorexic patients who did not maintain their attention longer on food pictures than on non-food pictures. This observation indicates attentional avoidance of food cues during a later attention process in anorexic patients, compared to healthy participants. Similarly, in two experiments by Shafran et al.[55,56], women with various types of eating disorder exhibited attentional avoidance of low-energy eating scenarios and attentional approach towards high-energy eating scenarios in a later attention process, in comparison to non-eating disordered control participants. In contrast, Smeets et al.[41] observed that eating-disorder patients (including a similar proportion of anorexic and bulimic patients) showed increased distraction by high-energy food words compared to healthy participants. This finding shows attentional approach towards high-energy food cues in eating-disorder patients. Contradictory to these studies, which observed significant differences in attention allocation for food between eating-disorder patients and healthy control groups, Veenstra and de Jong[57] reported that both healthy controls and eating-disorder patients alike, showed attentional avoidance of high-energy food (500 ms data).

To summarise, findings on an attention bias for food in eating-disorder patients are also contradictory. Giel et al.[54] and also Shafran et al.[55,56] observed attentional avoidance of food cues during a later attention process in eating-disorder patients when compared to healthy controls. However, there is also evidence that eating-disorder patients show increased distraction by food cues[41] in comparison to healthy controls, that eating-disorder patients show increased attention towards (high-energy) food[55,56] and that eating-disorder patients initially

fixate increasingly more often on food than on non-food cues ([54], result of one sample t test within anorexia nervosa patients). However, there is also evidence that eating-disorder patients do not differ from healthy controls in avoiding to look at high-fat food cues[57]; see Table 2 for an overview of studies.

### Attention bias for food and restrained eating

An overview of studies on restrained eating and attention bias for food is provided in Table 3. Two studies reported some evidence for increased attention approach of food cues in restrained eaters when compared to unrestrained eaters. For example, one study reported that restrained eaters, compared to unrestrained eaters, detected high-energy food targets faster than non-food targets (e.g. vehicles) in a matrix of non-food distractors of another category (e.g. musical instruments) yet restrained eaters were also faster to disengage their attention from food cues to find another non-food cue (e.g. a vehicle)[58]. However, when closely inspecting the depicted graph in this article it seems that the reported differences in attention bias scores were due to groups differences during non-food/non-food trials, as restrained and unrestrained eaters seem to have very similar scores during food relevant trials. Another study reported that restrained eaters reacted faster to high-energy food pictures than to non-food pictures in a flanker task[59], thereby suggesting attentional approach towards food cues in restrained eaters. Forestell et al.[60], also using a flanker task, reported that when hungry, unrestrained eaters were distracted by high-energy flankers regardless of whether they reacted to high- or low-energy targets, whereas restrained eaters were only distracted by high-energy flankers when they responded to low-energy targets. This finding suggests that restrained eaters feel conflicted when seeing high-energy food while aiming for low-energy food, when hungry. However, restrained and unrestrained eaters did not differ in their responses to high and low-energy food pictures when they were satiated. Together, these studies suggest that restrained eaters pay increased attention to (high-energy) food in comparison to unrestrained eaters (and low-energy food). In addition, findings from a study that assessed a temporal (i.e. not spatial) component of attentional processing showed that restrained eaters prioritise processing of food cues to a larger extent than unrestrained eaters, even if this could interfere with their (unrelated) task performance[61].

In contrast to these findings, there is also evidence that restrained eating is associated with attentional avoidance of high-energy food pictures in a later stage of attention processing ([62], data on 500 ms disengagement scores). Results from this study[62] further showed that in general all participants, unrestrained as well as restrained eaters, displayed attentional avoidance of (high-fat) food cues. Similarly, Hollit et al.[58] observed that restrained eaters were faster than unrestrained eaters to disengage their attention from food cues when searching for a non-food cue which could

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**Table 2.** Summary of food-related attention bias studies in ED and control participants (2007–2011)

| Reference | Sample | Paradigm | Measure | Attention components/ stimulus duration | Stimulus type | Stimulus content | Main findings |
|---|---|---|---|---|---|---|---|
| Shafran *et al.*[55] (study 1) | ED patients (*n* 23; i.e. three AN, six BN, fourteen EDNOS) Anxious women (*n* 19) Healthy control with low shape concerns (*n* 31) Healthy control with moderate shape concerns (*n* 21) Healthy control with high shape concerns (*n* 23). | VP | RT | 1000 ms | Picture pairs | Food-trials:†† 'Positive eating'(i.e. eating situations with LC food) – non-food control, 'Negative eating'(i.e. eating situations with HC food) – non-food control, 'Neutral eating' (i.e. objects related to eating or food preparation) – non-food control | ED > Control groups† |
| Smeets *et al.*[41] | ED (*n* 66; i.e. twenty-one AN restrictive, twenty-three AN purging, twenty-two BN), Healthy control (*n* 59) | VS | RT | Speeded detection Increased distraction | Word matrix | Food-trials:‡‡ HC – Non-food control, LC – Non-food control | *Speeded detection:* No evidence for speeded detection in ED patients *Increased distraction* (*HC distractors*):ED > Control group |
| Shafran *et al.*[56] (study 1) | ED patients (*n* 82; i.e. 50 ED-NOS including 6 BED, twenty-seven BN, five AN); Healthy control, age-matched (*n* 44) | VP | RT | 1000 ms | Picture pairs | Food-trials:†† 'Positive eating'(i.e. eating situations with LC food) – non-food control, 'Negative eating'(i.e. eating situations with HC food) – non-food control, 'Neutral eating' (i.e. objects related to eating or food preparation) – non-food control | ED > Control groups† |
| Giel *et al.*[54] | AN patients (*n* 19; i.e.; fourteen AN restricting, five AN purging), Healthy control fasted (8 h) (*n* 19) Healthy control (not hungry) (*n* 19) | FV | EM | Direction bias, initial fixation duration, duration bias (3000 ms) | Picture pairs | Food – non-food control | *Direction bias:* AN = Control groups‡ *Initial fixation duration bias:* AN = Control groups§ *Duration bias:* AN < Control groups |
| Veenstra & de Jong[57] | Restricting AN-like patients (*n* 88; i.e. forty AN, forty-eight AN subgroup EDNOS) Healthy controls (*n* 76) | EC‖ | RT (300, 500, 1000 ms) | Cue validity effect, engagement, disengagement | Pictures | High-fat food, low-fat food, non-food control | 300 ms: No food-related bias 500 ms: *Cue validity:* AN = Control group¶ *Engagement:* AN = Control group¶ *Disengagement:* No food-related bias 1000 ms: No food-related bias |

ED, eating disorder patients; AN, anorexia nervosa patients; BN, bulimia nervosa patients; EDNOS, eating disorder not otherwise specified patients; BED, binge-eating disorder patients; VP, visual probe task; VS, visual search task; FV, free viewing; EC, exogenous cueing task; EM, eye movements; RT, response latencies; HC, high-energy food cues; LC, low-energy food cues.

† Note that in this case>means that stronger attention bias were observed in ED (i.e. ED showed significantly more attentional avoidance of 'positive eating' and significantly more attentional approach for 'negative eating' stimuli).

‡ Note that AN directed significantly more attention to food than non-food cues.

§ Note that healthy controls remained with their attention significantly longer on food cues than non-food cues.

‖ Third of the participants received a stimulus duration of 300 ms, third of the participants received a stimulus duration of 500 ms, third received a stimulus duration of 1000 ms.

¶ Both groups showed attention avoidance (i.e. significant negative cue-validity effect and less attentional engagement) of high fat food (but not low-fat food or non-food cues).

†† The VP included also shape/weight trials to assess an attention bias for weight and shape information, yet results on this bias were not of interest in this review on attention bias for food and are therefore not reported here.

‡‡ During this study another VS with body-related words was conducted to assess an attention bias for body-related information, yet results on this bias were not of interest in this review on attention bias for food and are therefore not reported here.

**Table 3.** A summary of food-related attention bias studies in restrained and unrestrained eaters (2000–2013)

| Reference | Sample | Paradigm | Measure | Attention components/stimulus presentation | Stimulus type | Stimulus content | BMI | Main findings |
|---|---|---|---|---|---|---|---|---|
| Boon et al.[65] | 29 RS, 30 URS | VP | RT | 500 ms | Word pairs | Food words – non-food control, weight/shape –non-food control | n.sp. | RS = URS |
| Hollitt et al.[58] | 38 RS, 40 URS | VS | RT | Speeded detection, Increased distraction | Word matrix | HC food words, Non-food control | RS = URS[sr] | Speeded detection: RS > URS[a] Increased distraction: RS < URS |
| Ahern et al.[64] | Overall 61, median-split for RS | VP | RT | 500 ms | Picture pairs | Appetising food – non-food control, non-appetising food – non-food control† | RS > URS[sr] | RS = URS[b] |
| Veenstra et al.[62] | 28 RS, 27 URS | EC | RT | Cue validity Attentional engagement, disengagement, 500 or 1500 ms‡ | Pictures | High-fat food, low-fat food, non-food control | RS > URS | At 500 ms:[c] *Cue validity* RS = URS *Engagement:* RS = URS *Disengagement:* RS = URS At 1500 ms: No food-related bias Correlation analysis: $r$(RS~disengagement high-fat food 500 ms): −0·38[*] |
| Forestell et al.[60] | Expt 1:§ 29 RS, 37 URS Expt 2:‖ 27 RS, 46 URS | FT | RT | 250 ms | Picture array | HC food, LC food | RS = URS | Expt 1§: RS = URS[b] Expt 2‖: *RS:* Slower if low energy flanked by high energy food, *URS:* Slower when high-energy food was present |
| Meule et al.[59] | 25 RS, 22 URS | FT | RT | 500 ms | Picture array | HC food, non-food control | RS > URS | If food target: RS > URS[a], Self-reported dieting success was negatively associated with attention bias for food |
| Neimeijer et al.[61] | 40 RS, 40 URS | RsVPT | RT | Temporal attention biases: Attentional blink T1 (second type rsvp trials), Attentional blink T2 (first type rsvp trials), Attentional blink after food distractor (third type rsvp trials), Backward interference (first type rsvp trials) | Pictures | HC food, threat, non-food control | RS > URS | Attentional blink T1: RS = URS Attentional blink T2: RS = URS, Attentional blink after (task-irrelevant) food distractor: RS > URS Backward interference: RS > URS |
| Wilson & Wallis[63] | 23 RS, 25 URS | mST | RT | n.sp. | Words | HC food, ego-threat, non-food control | RS = URS | RS = URS[b] |

Table 3. (*Cont.*)

| Reference | Sample | Paradigm | Measure | Attention components/stimulus presentation | Stimulus type | Stimulus content | BMI | Main findings |
|---|---|---|---|---|---|---|---|---|
| Werthmann *et al.*[68] | 24 RS, 21 URS | VP | EM, RT | Direction bias (EM) Initial fixation duration (EM) Duration bias (EM) 2000 ms (RT) | Picture pairs | HC food – non-food control | RS = URS | RS = URS[b] |

RS, restrained eaters, URS, unrestrained eaters; VP, visual probe task; VS, visual search task; EC, exogenous cueing task; FT, flanker task; mST, modified Stroop Task; rsVPT, rapid serial visual presentation task; EM, eye movements; RT, response latencies; HC, high-energy food cues; LC, low-energy food cues; n.sp., not specified; sr, self-report.
† Note that picture pairs were individualised for participants.
‡ Half of the participants received a stimulus duration of 500 ms, and the other half of 1500 ms.
§ Under satiety conditions.
|| Under hunger conditions, *P < 0.05.
a A stronger attention bias, thus in this case faster reactions.
b Note that a significant stronger attention bias for food *v.* non-food cues was reported (i.e. attentional approach for food cues).
c Note that a significant stronger attention bias for non-food *v.* food cues was reported (i.e. attentional avoidance of food cues).

also be interpreted as attentional avoidance in a later stage of attentional processing.

The studies discussed earlier found significant differences between restrained and unrestrained eaters in an attention bias for food, despite opposing patterns of results. However, several other studies did not yield significant differences in attention bias, based on restraint status: a study that applied a modified version of the Stroop task, which can disentangle early and later attentional components, reported that all participants, irrespective of their restraint status, were significantly slower to disengage their attention from food words than from control words[63]. Moreover, two studies using response latency based visual probe tasks yielded no significant differences in attentional bias between restrained and unrestrained eaters[64,65]. Thus, these findings indicate that restraint might not be associated with biased attention allocation for food cues.

One possible explanation for the inconsistent pattern of results could be that restrained eaters are torn in an approach-avoidance conflict between wanting to eat and at the same time wanting to pursue their dieting goals, which could affect their attention processing of tempting food cues[64,66]. This approach-avoidance conflict could lead to the net-effect of a null finding when testing this hypothesis by relying on an indirect attention assessment that cannot provide a dynamic course of attention allocation. Another possibility for the divergent results of previous studies is that attention bias studies in restrained eaters are confounded by BMI differences between restrained and unrestrained eaters: restrained eaters are often heavier than their unrestrained counterparts ([67], and see also Table 3). Accordingly, one study that used eye-tracking and matched weight of restrained and unrestrained eaters, found that all participants had biased attention towards food cues (over non-food cues), with no difference between restrained and unrestrained eaters[68]. This finding suggests that not restraint *per se*, but rather weight problems (i.e. overweight and obesity) could be an underlying factor that contributed to previously observed differences in attentional bias for food between restrained and unrestrained eaters.

To summarise, two of the nine studies suggested attention approach of food cues in restrained eaters. Note however, that one of these studies, Hollit *et al.*[58], also found faster disengagement from food cues in restrained eaters, which could be interpreted as attentional avoidance. One study suggested that restrained eaters were distracted by high-energy food when focusing on low-energy food while being hungry[60]. Another study suggested that restrained eaters prioritise processing of food cues more than unrestrained eaters[61]. However, the majority of the published studies (*n* 5) observed no significant differences between restrained and unrestrained eaters in attention processing of food cues[62–65,68]. Three of these five studies suggested that attention is biased towards food *v.* non-food cues in all tested participants, irrespective of their restraint status [63,64,68] (Boon *et al.*[65] did not test explicitly whether attention bias for food cues *v.* non-food cues

was increased (or decreased) in all participants.) and one study suggested that all participants avoided looking at food[62]. Together, these results might suggest that food is a highly relevant stimulus in the environment in general, but not only for restrained eaters. Moreover, the results highlight the need to account for restraint and weight status when measuring attention bias for food.

### Attention bias for food and food intake: a causal relationship?

Recently, five studies have been published using an attention bias modification to test if an attention bias for food leads to increased intake of that food; see Table 4 for an overview of studies. Usually, attention bias modification entails that the contingencies of a visual probe task are manipulated in a fashion that the probe either replaces the food stimulus in all (or most) trials (thereby modifying attention towards food cues) or that the probe replaces the contrast category in all (or most) trials (thereby modifying attention away from food cues).

Hardman et al.[69] used a visual probe task with high-fat cake and non-food pictures to modify attention bias. They included a no-bias-induction control condition, (i.e. the probe replaced food cues in 50 % of trials and non-food cues in 50 % of trials), an 'Attend cake' condition (i.e. the probe always replaced the high-cake picture) and an 'Avoid cake' condition (i.e. the probe always replaced the non-food picture). Results indicated a marginal significant change from pre- to post-training in attention bias for cake: participants in the 'Attend cake' condition had a stronger attention bias for cake after the attention modification, in comparison to the other conditions. However, no significant differences in intake (of cake and other food items) were observed between conditions. The present study thus indicates that attention bias for a certain food might not change easily due to a modification task, and that marginal changes in attention bias do not influence subsequent intake.

Kemps et al.[70] conducted two experiments, also applying a manipulated variant of the visual probe task, with chocolate-food and non-chocolate food stimuli. Neither study included a no-bias-induction control group. Participants were either trained to attend to chocolate stimuli or to avoid looking at chocolate stimuli (to look towards non-chocolate food). Their findings indicated that in both experiments attention bias for chocolate v. non-chocolate food changed with the training: participants in the 'Avoid chocolate' condition had significantly less attention bias for chocolate than participants in the 'Attend chocolate' condition after the training. Moreover, these changes translated to subsequent food intake: participants in the 'Avoid chocolate' condition ate significantly less chocolate muffins during a taste test and a similar amount of blueberry muffins when compared to participants in the 'Attend to chocolate' condition (Expt 1). In the second experiment, participants in the 'Avoid chocolate' condition again ate significantly less chocolate muffins but significantly more blueberry muffins than participants who had to

attend to chocolate stimuli. Thus, these experiments provide evidence that experimentally changing attention bias towards or away from a certain food influences subsequent food intake. However, because no control group was employed, it is impossible to determine whether modifying attention away from chocolate decreased chocolate intake or whether modifying attention towards chocolate increased chocolate intake in the respective conditions.

In a similar experiment, Kakoschke et al.[71] trained participants to attend healthy food (and look away from unhealthy food) or to attend unhealthy food (and look away from healthy food). Again, a no-bias-induction control group was missing. The results concurred with those of Kemps et al.[70], in that attention bias towards healthy food was modifiable. Prior to the attention modification, all the participants had an attention bias towards unhealthy food. This attention bias for unhealthy food did not further increase in the unhealthy training condition (maybe due to a ceiling effect). However, participants in the healthy condition significantly increased their attention bias towards healthy food. Results also yielded that participants in the 'healthy' condition ate a significant greater proportion of healthy food than unhealthy food during a taste test offering both kinds of foods compared to participants in the 'unhealthy' condition.

Whereas the previous studies tested attention bias modification within non-clinical (student) samples, Boutelle et al.[72] studied attention bias modification for food within a clinical sample of overweight and obese children. A modified visual probe task with food words and non-food words was used to modify attention away from food in the training condition, whereas in the control condition contingencies in this task remained unaltered. Prior to and after the attention modification, children's intake of snack food in the absence of hunger was assessed. Results yielded that attention bias for food words remained the same in the training group, yet the control group showed marginally increased attentional bias towards food words after the control task. This finding translated to food intake: whereas children in the training condition ate a similar amount of food before and after the training task, the control group significantly increased their intake after the (control) task. The authors suggested that training to look away from food words helped children to maintain a similar level of attention bias for food and similar amount of intake, whereas looking in 50 % of trials towards food might have increased attentional bias and subsequent intake in the control group.

The previously discussed studies relied on a pre- and post-assessment of attentional bias to account for changes in attentional processing of food cues, yet one study integrated a measure for attentional allocation during the attention modification paradigm[73]. An anti-saccade task was applied to modify attention bias for chocolate. Participants either had to saccade quickly towards chocolate and away from shoe cues ('Attend chocolate' condition), or had to look quickly towards

**Table 4.** A summary of attention bias modification studies for food-related attentional bias and food intake (2013–2014)

| Reference | Sample | Paradigm | Training trials (n) | Stimulus type | Stimulus content | Conditions | Assessment AB | Assessment Intake | Main findings |
|---|---|---|---|---|---|---|---|---|---|
| Hardman et al.[69] | Students (N = 60, including thirty-five females, twenty-five males) | mVP | 516 | Picture pairs | High-fat cake – non-food control | 'Attend cake', 'Avoid cake', 'Control' | RT, 500 ms, pre- and post-training | High-fat cake, low-fat cake, high-fat crisps, low-fat crisps | AB (for cake): Trend for increase in 'Attend cake' condition† Intake: No effects |
| Boutelle et al.[72] | Twenty-nine OV/OB children (44.8% females) | mVP | 288 | Word pairs Food words v. non-food words | Food words – non-food words | 'Avoid food', Control | RT, 500 ms, pre- and post-training | EAH, pre and post training | AB (for food): Trend for increase in control group˚ Intake: Control > 'Avoid food' |
| Kakoschke et al.[71] | 146 Students (all females) | mVP | 256 | Picture pairs | Healthy food – unhealthy food | 'Attend healthy food' 'Avoid healthy food' | RT, 500 ms, pre- and post-training | Two healthy, two unhealthy foods | AB (for healthy food): 'Attend healthy food' > 'Avoid healthy food' Intake‡: 'Attend healthy' > 'Attend unhealthy' |
| Kemps et al.[70] | Study 1: 110 students (all females) Study 2: eighty-eight students (all females) | mVP | 256 | Picture pairs | Chocolate – non-chocolate | 'Attend chocolate' 'Avoid chocolate' | RT, 500 ms, pre- and post-training | Chocolate muffin, blueberry muffin (i.e. non-chocolate food) | AB (for chocolate): 'Attend chocolate' > 'Avoid chocolate' Intake: Intake chocolate muffin:§ 'Avoid chocolate' < 'Attend chocolate' Intake blueberry muffin:‖ 'Avoid chocolate' > 'Attend chocolate' |

| Werthmann et al.[73] | Fifty-six students (females) | mAST | 320 | Pictorial stimuli | Chocolate or shoes | EM, 500 ms | 'Attend chocolate', 'Attend shoes' | Chocolate | AB (for chocolate): 'Attend chocolate' > 'Attend shoes' Intake¶: Higher accuracy: 'Attend chocolate' > 'Attend shoes'. Lower accuracy: 'Attend chocolate' < 'Attend shoe' |

mVP, modified visual probe task; mAST, modified anti-saccade task; RT, response latencies; AB, attention bias for the respective food cues (e.g. chocolate, cake, healthy food); EAH, eating in the absence of hunger.
† Note that a marginal significant interaction of time and condition on attention bias scores was observed.
‡ Note that the amount of healthy snack food consumed was compared between conditions as a proportion of total (including healthy and unhealthy) snack food.
§ In Expt 1 and in Expt 2.
|| In Expt 2 only.
¶ Note that a significant interaction of accuracy and condition on intake was observed.

shoes and away from chocolate ('Attend shoes' condition). To account for the accuracy with which participants followed these instructions, participants' eye-movements were recorded during the task. Results showed that accuracy significantly moderated the outcome: participants with higher accuracy ate more chocolate when they had to attend to chocolate, and ate less chocolate when they had to attend to shoes. However, the results were reversed for participants with lower accuracy. Even though this interaction strongly suggests that attention for food is related to subsequent food intake, the question of causality remains in this study because it was unclear what caused the differences in accuracy (and thus influenced attention processing) during the modification training.

To summarise, results so far suggest that experimentally induced change in attention bias for food relates to changes in intake. Most of the currently published studies showed that attention bias modification towards (or away from) certain food increases (or decreases) intake of this food[70,71,73]. Unfortunately, in most studies, a no-bias-induction control group was missing and hence it remains unclear whether an increase in attention bias leads to increased food intake, or whether a decrease in attention bias for food leads to a decrease in food intake. To sum up, at the present state of research, results are considerably promising that attention bias modification influences food intake and thus suggest that an attention bias for food is causally related to intake.

### Attention bias for food and craving

We also briefly reviewed findings on the relationship of craving or hunger and attention bias for food, based on the included studies. Most of these studies measured craving or hunger but did not examine directly (e.g. by testing correlations) if craving and/or hunger is associated with attention biases for food. Of the thirty reviewed studies, eleven measured craving[46,48,50,51,59,61,62,68,72–74] and seventeen assessed hunger[19,44,47–51,54,58,60–63,65,68,69,72] (with an overlap in seven studies assessing both). Eleven of these studies tested the relation of attention bias and craving or hunger statistically. Most studies (n 6) reported a positive association of an early attention process (e.g. direction bias) with self-reported craving or hunger[19,44,46,48–50]. Only two studies reported null findings for correlations of an early attention component and craving[51] and/or hunger[47,51]. Findings seem less consistent for a later attention component (e.g. dwell-time bias), as one study found a positive correlation of attention maintenance and hunger[44], whereas another study yielded that hunger negatively related to attention maintenance on (fried) food[49]. No other study reported significant findings on the relation of a later attention component and hunger or craving. Hence, these results suggest that specifically the early (more automatic) attention component is related to subjective (self-reported) experiences of hunger or craving. Interestingly, whereas most studies[69,70,72,73] on attention bias modification assessed

craving or hunger, only Kemps *et al.*[70] observed a change in craving for chocolate in line with change in attention bias for chocolate. The other studies did not find an effect of attention bias (modification) on self-reported craving. This suggests that the effect of attention bias modification on food intake might not necessarily transfer to the subjectively experienced (explicit) reports of craving.

## Conclusion and implications

The aim of this selective review was to summarise studies testing if an attention bias for food reflects appetitive motivation or worry about food intake, and if attention bias for food is causally related to food intake. The present state of research provides no consistent empirical evidence on reliable individual differences in attentional bias for food, depending on weight status or eating concern. Evidence for an increased attention bias for (high-energy) food in obese and overweight participants in comparison with healthy-weight participants is conflicting. Similarly inconsistent results were obtained for eating-disorder patients in comparison to non-clinical groups. The present research on attention biases and restrained eating is also equivocal, but seems less contradictory with a majority of published studies reporting no differences in an attention bias for food between restrained and unrestrained eaters. Interestingly, there is also empirical evidence showing that healthy-weight, non-eating disordered and unrestrained participants have food-related attention biases, suggesting that everyone might have an attention bias for food.

Methodological differences in the reviewed studies might explain the divergent results: the reviewed studies were inconsistent with regard to the assessment of attention bias (direct assessment via eye-tracking *v.* indirect assessment of response latencies), the temporal components of attention bias (early *v.* later attention processes) and specific characteristics of heterogeneous (sub)samples (e.g. in eating-disorder research combining groups of anorexic, bulimic and other eating-disorder patients). Moreover, different choices in stimuli sets could have contributed to mixed findings, because it is possible that the contrast category influences the context in which the relevant stimuli are automatically evaluated (see for a similar argumentation when using implicit measures [75–77]). For example, by presenting high-energy food together with low-energy food, participants might be primed with the concept of 'health' whereas a combination of high-energy with neutral non-food stimuli renders the activation of this association less likely. These methodological considerations highlight not only the need for refined and valid methods to assess attention bias in an eating context, but also call for replication of previous studies to test how reliable the applied methods are.

Overall, this selective review of existing literature cannot provide a definite answer on the question if attention bias for food reflects worry about intake or craving. However, based on the relatively consistent findings on attention bias modification more evidence speaks for an addiction account: an attention bias for food leads to increased intake. Similarly, even though there is a paucity of studies, positive results for the relation of attention bias for food and craving were obtained. However, it is to note that (experimental) research testing if an attention bias can reflect worry, especially within overweight or restrained samples, is relatively scarce. Overall, research on an attention bias for food seems to corroborate with an addiction account of the role of attention bias for food[43] suggesting that an attention bias towards food is the expression of increased hedonic motivation for food and could even causally contribute to overeating.

This knowledge could be useful for future research: an experimental modification of attention biases could help to understand the working mechanisms of attentional processes and can inform on effective treatment options, such as incorporating an attention bias modification training in obesity treatments or as (part of) a relapse prevention programme. On a societal level, another implication could imply targeting the visibility of (high-energy) food temptations in our surroundings to prevent susceptible individuals from being lured into craving and overeating by their attentional bias for food.

## Conflicts of Interest

None.

## Authorship

J. W. drafted this manuscript. All authors contributed and/or commented on an earlier and the final version of this review.

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