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Attentional bias to food-related visual cues: is there a role in obesity?

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The incentive sensitisation model of obesity suggests that modification of the dopaminergic associated reward systems in the brain may result in increased awareness of food-related visual cues present in the current food environment. Having a heightened awareness of these visual food cues may impact on food choices and eating behaviours with those being most aware of or demonstrating greater attention to food-related stimuli potentially being at greater risk of overeating and subsequent weight gain. To date, research related to attentional responses to visual food cues has been both limited and conflicting. Such inconsistent findings may in part be explained by the use of different methodological approaches to measure attentional bias and the impact of other factors such as hunger levels, energy density of visual food cues and individual eating style traits that may influence visual attention to food-related cues outside of weight status alone. This review examines the various methodologies employed to measure attentional bias with a particular focus on the role that attentional processing of food-related visual cues may have in obesity. Based on the findings of this review, it appears that it may be too early to clarify the role visual attention to food-related cues may have in obesity. Results however highlight the importance of considering the most appropriate methodology to use when measuring attentional bias and the characteristics of the study populations targeted while interpreting results to date and in designing future studies.

Incentive sensitisation: Weight status: Eye tracking: Visual probe: Stroop

Prevalence of overweight and obesity has now reached epidemic proportions with more than 1·4 billion adults considered as overweight and of these, over 500 million being obese worldwide[1]. On a fundamental level the cause of obesity is linked to an imbalance of energy intake *v.* energy expenditure; however, it is now evident that obesity is a multifactorial condition that arises from interactions between genetic and environmental factors[2]. One such factor is the present 'obesogenic' environment that is characterised by a wealth of highly palatable, energy-dense foods[3]. These foods are heavily represented in the visual environment for example, through advertising and it has been suggested that frequent exposure to these forms of food-related cues may impact on eating behaviours and food choices[4–6].

According to the theory of incentive sensitisation, 'addictive substances' modify reward-related pathways in the brain leading to hypersensitisation of reward-related stimuli[7]. This results in increased salience to reward-related stimuli resulting in these stimuli becoming more 'attention grabbing'. It has been proposed that this heightened awareness is the consequence of repeated exposure to a particular stimulus and the association between the stimulus and a rewarding experience, which results in related cues becoming salient. The stimulus related to the rewarding experience may then attract greater attention and in turn trigger feelings of cravings that may potentially impact on behaviours and choices. This process is often referred to as attentional bias and is based on the theory of incentive sensitisation put forth by Robinson and Berridge[7]. This theory has been applied to drugs of addiction[8], smoking[9] and alcohol research[10]. More recently, it has been suggested that food-related stimuli may also have the ability to

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Table 1. A summary of food-modified Strop task measures of attention to food-related stimuli in overweight/obese *v.* normal weight populations

Author	Study population	Measure of attention	Stimuli and presentation time	Hunger condition	Main findings
Nijs *et al.*[23]	Twenty OB (16F;4M), twenty NW (16F;4M)	Food-modified Stroop task	HED food words matched to control words 2000 ms	Light meal 2 h before testing	Positive correlation between reaction time bias scores and food craving scores in OB participants
Phelan *et al.*[24]	Fourteen OB (12F;2M), nineteen NW (17F;2M), fifteen long-term weight loss maintainers (13F;2M)	Food-modified Stroop task	HED and LED food words matched to control words 3 × 45 s subsets	Fasted	Weight loss maintainers had slower reaction times to HED words than NW or OB participants

OB, obese; F, female; M, male; NW, normal weight; HED, high energy dense; LED, low energy dense.

capture attention and activate reward pathways in the brain thus making visual food cues more salient to the observer[11,12]. The processing of reward and pleasure is mediated by the mesocorticolimbic dopamine system, in particular the ventral tegmental area, the ventral striatum and nucleus accumbens. Activation of these reward pathways occurs on exposure to drugs of addiction; however, recent neuroimaging studies have indicated that these pathways may also be activated on exposure to foods high in fat and/or sugar (see Stice *et al.*[13] for a review).

Previously, detection and awareness of food within the visual environment would have been considered as a necessary evolutionary adaption to survive[14]; however, in today's Western environment, such a resourcefulness could be contributing to the current obesity epidemic[15]. Research has suggested that some individuals may have greater attentional bias to food-related visual cues[16–18] within their environment (for example, being more 'tuned in' or aware of the sight of a food or a related food image) and it is possible that they may be at greater risk of overeating and subsequent weight gain. It is therefore of interest to further investigate whether some individuals are more susceptible to increased attention to food-related stimuli, in particular, potential weight group differences considering the current rates of overweight and obesity.

Several methods exist for the assessment of attentional bias and are often referred to as indirect and direct methods[19]. These methods have previously been used to examine attention to food-related stimuli in normal weight populations in both a fasted and satiated condition[20–22]. More recently research has begun to focus on visual attention to food-related stimuli in individuals who are overweight or obese[15,23–29]. Results from these studies however have been inconsistent and this may be due in part to the methodology used to measure attention. In this review, both indirect and direct behavioural methods of measuring attentional bias to food-related stimuli in normal weight and overweight/obese adult populations are discussed and questions are raised as to the most appropriate methodology to use when assessing attentional bias to visual food cues.

Methodologies used to measure attention: indirect *v.* direct methods

Attentional bias can be measured using behavioural methods, consisting of indirect and direct measures. Studies investigating attentional bias to food-related stimuli have employed a variety of these methods either as a sole measure of attention or in combination and results appear to depend on the methodology used, the type of stimuli employed for the attentional task, stimuli presentation time and/or the study cohort targeted. The most common indirect and direct behavioural methods used to date in food-related attentional bias research will now be described.

Indirect methods for assessing attention to food-related visual stimuli

The most common indirect methods used to measure attentional bias to visual food cues in normal weight *v.* overweight/obese adults have been the food-modified Stroop task (presented in Table 1) and the visual probe task (presented in Table 2).

Food-modified Stroop task

The classic Stroop task[30] has been adapted from cognitive psychology to examine human attention and information processes. This task involves the presentation of words printed in different colours of ink consisting of control words and stimuli of interest-related words. A delay in correctly naming the colour of ink in which the word is printed is considered as an interference effect and is traditionally considered as an example of cognitive competition.

More recently, the classic Stroop task has been modified to measure attention to food-related stimuli. In a food-related Stroop task, participants are exposed to food-related words and control words (non-food-related words matched for word length, complexity and familiarity) and instructed to name as quickly and accurately as possible, the colour in which each word is printed while attempting to ignore the content of the word. Attentional bias is then determined from the length of time it takes to colour name a food-related word as compared with a non-food-related word. A slower reaction time in successfully naming the colour of ink in which a food-related word is printed is usually considered as having a greater attentional bias towards the content of the food-related word; however, it has been suggested from other areas of attentional bias research (e.g. substance abuse[31]) that some individuals may attempt to divert attention away from a stimulus as a means to control

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Table 2. A summary of visual probe task and eye-tracking measures of attention to food-related stimuli in overweight/obese *v.* normal weight populations

Author	Study population	Measure of attention	Stimuli and presentation time	Hunger condition	Main findings
Castellanos *et al.*[15]	Eighteen OB females, eighteen NW females	VPT and ET	Pairs of HED and LED food images matched to control images 2000 ms	Fasted and fed (within-subject design)	Increased gaze direction and duration to food images for all participants when hungry, maintained in OB females when fed. Increased gaze duration and direction to HED food images compared with LED food images
Loeber *et al.*[25]	Twenty obese (13F;7M), twenty NW (13F;7M)	VPT	Pairs of food images matched to control images 50 ms	Refrain from eating 3 h prior to testing	No effect of image type (food vs. non-food) or weight group
Gearhardt *et al.*[26]	100 OW/OB females	VPT	Food images high in fat and/or sugar Food images low in fat and/or sugar 500 ms	Not controlled	Positive correlation between BMI and reaction times to food images high in fat and/or sugar
Nijs *et al.*[27]	Twenty-six OW/OB females, forty NW females	VPT and ET	Pairs of HED food images matched to control images 100 ms and 500 ms (VPT) 2000 ms (ET)	Fasted and fed (between-subject design)	Faster visual probe task reaction times in 500 ms trials to food images in NW as compared with OW/OB females
Werthmann *et al.*[28]	Twenty-two OW/OB females, twenty-nine NW females	VPT and ET	Pairs of HED food images matched to control images 2000 ms	2 h fast followed by a experimental task	Increased gaze direction bias to food images in OW/OB females as compared with NW females
Graham *et al.*[29]	Twenty-one low BMI females, fifteen high BMI females	ET	Pairs of HED savoury, HED sweet and LED food images 3000 ms	Not controlled	Increased direction bias to HED sweet foods in low BMI females as compared with high BMI females

OW, overweight; OB, obese; NW, normal weight; VPT, visual probe task; ET, eye-tracking; HED, high energy dense; LED, low energy dense.

feelings of cravings which may also result in a slower colour naming time.

This measure of attentional bias has been used in two studies investigating potential weight group differences in attentional processing of food stimuli in an adult population. The first conducted by Nijs *et al.*[23] used high energy-dense food-related words and observed no differences in attentional processing of food stimuli between normal weight and obese participants. Similarly in 2011, Phelan *et al.*[24] found no weight group differences in attentional processing of food words between normal weight and obese participants but did observe slower reaction times to high energy-dense food words in a group of long-term weight loss maintainers with a previous history of being overweight/obese. Although well recognised in the field of attentional bias research, some questions have been raised in regards to the index of information processing measured by the food-modified Stroop task. Slower reaction times may reflect an increase in attention to the content of the word or diversion of attention from food-related stimuli as a means to control food cravings and desire to eat. This was demonstrated by Phelan *et al.*[24] who although as previously discussed did not identify weight group differences in attentional processing of food words between normal weight and obese women, did report slower reaction times in colour naming of high energy-dense food-related words in weight loss maintainers. This slower colour naming of food-words could be interpreted as a possible deliberate effort to restrict (i.e. shift attention away from) attentional responses to food stimuli as a means of controlling food cravings. Finally, it has been suggested that as individuals tend to be exposed to reward-related images through the visual environment, the use of reward-related words normally employed in Stroop tasks may not be considered as ecologically valid and representative of visual cues as reward-related images[32,33].

The classic Stroop task is one of the most widely used tests of substance-related attentional bias; however, attentional research has continued to evolve in an attempt to measure how participants' visual attention is allocated to particular stimuli in a more ecologically valid manner by using simultaneously competing reward-related images or words. One such method is the visual probe task[34].

Visual probe task

In a food-related visual probe task, participants are exposed to a food-related word or image matched to a control word or image simultaneously presented side by side on a computer screen. The paired food words or images then disappear after a set period of time (usually 50–2000 ms) and a dot probe replaces one of the previous stimuli. Participants are instructed to respond as quickly as possible to the location of the probe and attentional bias is measured from the length of time it takes to successfully identify the location of a probe that replaces a food or non-food stimuli. In general, individuals react faster to probes that appear in visual areas that they have already expressed interest in, responding more

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quickly to a probe that appears in a visual display to which attention has already been directed compared with a probe that appears in an area to which individuals have not attended[35].

Visual probe task data appears to provide information on both initial orientation and maintenance of attention by varying the length of the stimulus presentation time (i.e. how long the image is presented on the screen). For example, Nijs *et al.* [27] using food stimuli presented for 100 ms (which they considered as an indication of initial attention allocation) found a main effect for image type with all participants, regardless of weight status (normal weight *v.* overweight/obese) having a greater attentional bias to food images as compared with control images. In comparison, using the same visual probe task and stimuli presented for 500 ms (which they considered to be an indication of maintained attention) in the same cohort of participants, a main effect for weight group was observed with normal weight females having significantly quicker reaction times to probes that replaced food images as compared with their overweight/obese counterparts. Castellanos *et al.*[15] also using a visual probe task, found no effects of weight status or hunger condition in attentional processing of food images in a group of normal weight and obese women with a stimulus presentation time of 2000 ms.

Similar to the Stroop task, it has been suggested that it can be difficult to interpret results obtained from visual probe tasks, particularly those with a longer stimulus presentation time (e.g. >500 ms) as it is not possible to measure shifts in attention between stimuli presented side by side or gauge participant disengagement from stimuli presented during the task[36,37]. This may in part explain the conflicting findings that have been observed in studies that have attempted to measure maintained attention to food-related stimuli using a visual probe task with longer stimulus presentation times[15,27] and indicates that this particular measure of attention may be more suitable for providing an indication of initial attention to visual food cues.

Direct methods and combination studies for assessing attention to food-related visual stimuli

The most common direct method used to measure attentional bias to visual food cues in normal weight *v.* overweight/obese adults has been the use of eye-tracking technology (presented in Table 2). A limited number of studies have used this method in combination with indirect methods or as a sole measure of attentional bias to food-related stimuli.

Eye-tracking

Recently, the use of novel eye-tracking technologies has been recognised as a direct method of measuring visual attention, overcoming some of the methodological issues encountered using the Stroop or visual probe task[31,36]. These eye-tracking systems record participants' eye-movements and interspersed visual fixations as they complete an attentional task. The duration of each visual fixation is presumed to represent the degree of cognitive processing whereas the point of visual gaze indicates the initial area of expressed visual interest. This method of assessing visual gaze allows for eye-movements to be monitored in a non-invasive manner while individuals are exposed to visual stimuli, providing a measure of attentional shifts that cannot be monitored using indirect methods[31]. It appears that different cognitive mechanisms may underpin the initial direction of allocated attention, the maintenance of visual attention to a particular stimuli and the disengagement of attention[38,39]. As previously discussed, shorter stimuli presentation times while using an indirect method are usually employed to measure initial attention. Longer presentation times are considered as a measure of maintained attention[31]. According to the work of Duncan *et al.*[40] 50 ms is the required time needed for an individual to shift their attention towards a particular stimulus of interest. Furthermore, Theeuwes[41] suggested that approximately 150 ms are required to disengage attention from a stimulus and shift attention to a competing stimulus of interest. From this, it would appear that when stimuli are presented side by side, for example in a visual probe task for a duration of 200 ms, any attentional bias that occurs, could be considered as an indication of initial attentional allocation alone since stimuli presentation time is not sufficient to allow for a measure of any further shifts in visual attention. To investigate maintained attention, many researchers have therefore used stimuli presentation times of 1000 ms or longer; however, interpretation of results from these studies have been conflicting. For example, a study conducted by Bradley *et al.*[42] investigating attentional bias to cigarette-related visual cues in smokers considered a stimuli presentation time of 500 ms to be a measure of initial directed attention. In comparison, Koster *et al.*[43] investigating attention to threat-associated stimuli, considered a stimuli presentation time of 500 ms as an indication of maintained attention. More recently, a review by Field *et al.*[31] examining attentional bias in addictive behaviours agreed with the suggestions of Koster *et al.*[43] that stimuli presentation times of 500 ms or greater could be interpreted as maintained attention and presentation times of 200 ms or less, considered a measure of initial attentional allocation. It is evident that there is some contradiction not only in food-related attentional bias research, but also attentional bias research as a whole of the most appropriate length of stimuli presentation time to successfully measure the difference stages of attentional allocation. This has led to some researchers using eye-tracking methodologies as a more comprehensive tool to allow for the continuous assessment of eye-movements as a measure of attentional allocation (both initial and maintained) and attentional disengagement.

Three studies have used eye-tracking in combination with a visual probe task (an indirect measure of attention) to investigate both initial and maintained visual attention to food-related stimuli in normal weight *v.* overweight/obese populations[15,27,28]. Interestingly, data obtained from eye-tracking and visual probe tasks used in these studies appear to yield different results despite both methods being used in the same participant cohort.

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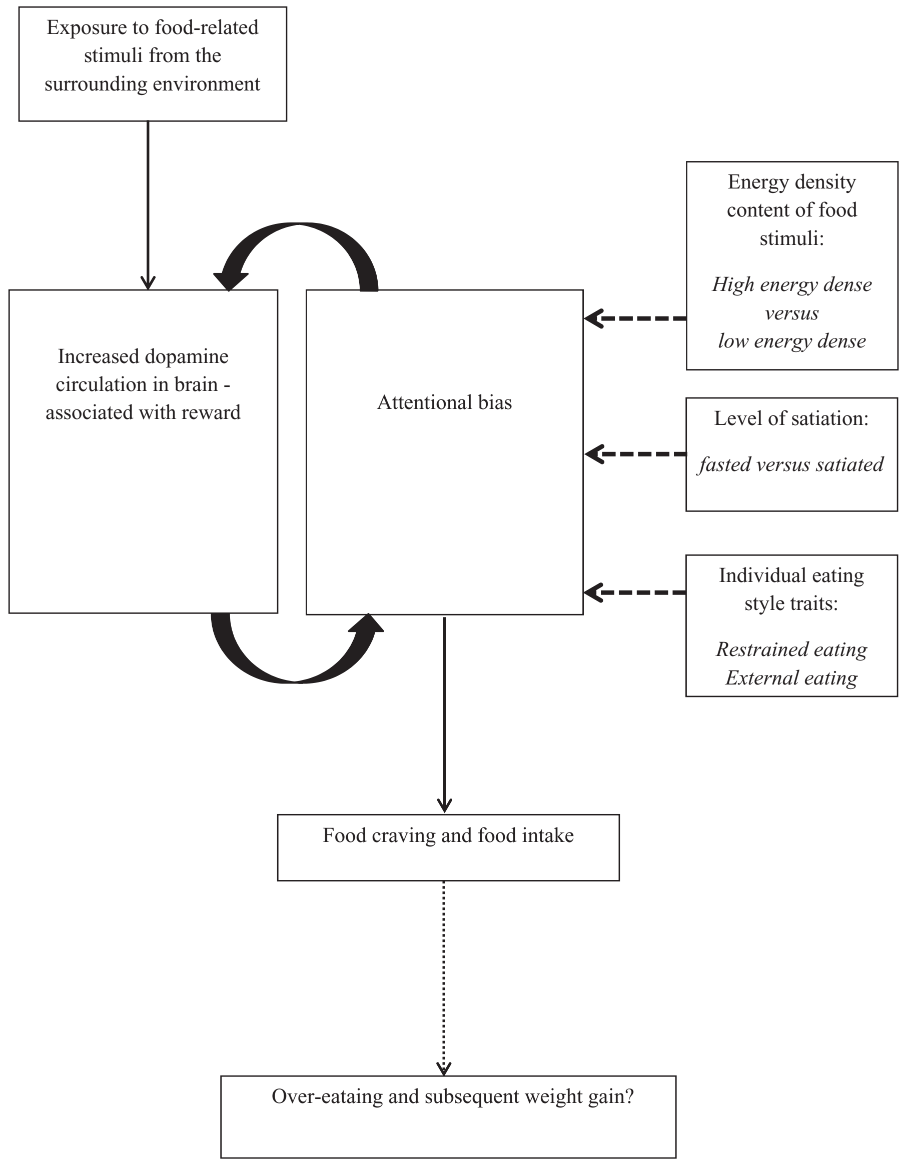

Fig. 1. The potential role of attentional bias to food-related stimuli in the development and maintenance of obesity (adapted from Franken *et al.*[63])

For example, Castellanos *et al.*[15] reported enhanced gaze direction and gaze duration obtained from eye-tracking data in both normal weight and obese females to food images while participants were in a fasted condition and this was maintained in the obese group even following satiation from consumption of a liquid-based meal, but found no weight group differences in reaction time data obtained from the visual probe task. Werthmann *et al.*[28] used eye-tracking coupled with a visual probe task and established increased gaze direction to food images in overweight/obese females as compared with normal weight females but results from reaction time data results did not yield any between weight group differences. Similarly Nijs *et al.*[27] also used a visual probe task plus recording of eye-movements and observed faster reaction times to a visual probe that replaced food-related stimuli, in normal weight females as compared with their overweight/obese counterparts but observed no differences between the two weight groups in eye-tracking data despite both measures being conducted in the same sample. Finally one study has used the monitoring of eye-movements as a sole measure of attentional processing of food-related images in normal weight *v.* overweight/obese females. Graham *et al.*[29] used eye-tracking as a measure of visual attention without the use of an indirect method and reported no differences in maintained visual gaze to food images as a function of BMI group but did observe greater initial attentional orientation to visual food cues in normal weight women as compared with their overweight/obese counterparts.

These conflicting results demonstrate that the choice of methodology, the length of stimuli presentation time and the type of stimuli used to measure visual attention may influence the results obtained even in studies that have employed two methods (an indirect and a direct method) to measure what could be considered as the same aspect of attentional processing. This indicates that future studies are necessary to clarify the most suitable measure of visual attention required to accurately measure potential weight group differences in the attentional processing of food-related stimuli.

Other methodological considerations

It appears that no consensus has been reached with regards to the most appropriate method to use in measuring attentional bias to food-related stimuli; however, as this novel area of obesity research grows, other factors have been recognised as having the potential to impact on attentional processing of visual food cues and as such, these factors may need to be taken into consideration when designing and subsequently interpreting results of studies conducted in the field. These factors include the levels of participant satiation, energy density of food-related stimuli, individual eating style traits and the weight status of the study population targeted. The proposed interactions between these factors are summarised in Figure 1. The potential of each will now be considered in relation to their possible impact on the attentional processing of visual food cues.

Effects of satiation

Several studies have investigated potential associations between self-reported levels of hunger and/or food cravings and attentional bias to food-related stimuli. From an evolutionary perspective, it would be expected that individuals may be more aware of their food-related environment when they are hungry as compared with when they are satiated[14]. For example, Geardhardt *et al.*[26] using a visual probe task found that self-reported hunger levels were a significant predictor of attention to food images in overweight/obese women. Similarly, Nijs *et al.*[27] reported that participants, regardless of weight status (i.e. normal weight *v.* overweight/obese) in a condition of hunger had faster reaction times to food-related stimuli presented for 100 ms than participants provided with a liquid-based study meal although it should be noted that the present study employed a between-subject rather than a within-subject design. In comparison, Loeber *et al.*[25] reported no association between levels of hunger and reaction times to food stimuli in a group of obese and normal weight women. Within these studies, although attentional bias was measured consistently using a visual probe task, there were significant variations in how hunger levels were assessed and/or whether hunger levels were manipulated as part of the study protocol. For example, Geardhardt *et al.*[26] recorded participant self-reported hunger levels using a 100 mm visual analogue scale; however, participants did not receive any instructions in regards to fasting prior to the study session and no study meal was provided. In comparison, Nijs *et al.*[27] using a between-subject design, recorded self-reported hunger levels using a visual analogue scale in participants following a 17 h fast and in participants provided with a liquid-based study meal. Loeber *et al.*[25] also assessed self-reported hunger levels using a visual analogue scale and participants were instructed to refrain from eating at least 3 h before the testing session.

Only one study has investigated potential weight group differences in attentional processing of food-related stimuli using a direct method of assessing attentional bias while taking into consideration the potential effects of hunger condition using a within-between subject design. Castellanos *et al.*[15] used a visual probe task and recording of eye-movements to assess attentional bias to food-related visual cues. Results demonstrated that following consumption of a liquid-based study meal, normal weight participants had lower levels of self-reported hunger and reduced attention to food cues as compared with obese females who maintained increased attentional bias to visual food cues despite also reporting lower levels of self-reported hunger. This suggests that a future work is needed to identify the most suitable method for conducting studies assessing and/or controlling for the potential impact hunger condition may have on the attentional processing of visual food cues, in particular employing the use of a within-between subject design using a validated method to assess self-reported hunger such as a visual analogue scale[44].

Effects of energy density of food-related cues

It has been suggested that attentional processing of visual food cues may be influenced by the energy-density content of foods, with several studies demonstrating increased attention to high energy-dense foods (those high in fat and/or sugar) as compared with food with a low energy density (those with a high water and/or fibre content)[45]. For example, Phelan *et al.*[24] reported greater attention to high energy-dense food images as compared with low energy-dense food images in a group of normal weight, recent weight loss maintainers and obese women. Similarly, Geardhardt *et al.*[26] also suggested that foods high in fat and/or sugar appear to grab attention more readily in a group of normal weight and obese women. Both of these studies however used an indirect method of measuring attentional bias by means of a visual probe task, which as previously discussed may present some issues with regards to the interpretation of results obtained.

Two studies however have used a more direct method using eye-tracking to assess the potential impact that the energy density of food images may have on attentional processing of food-related visual cues in normal weight *v.* overweight/obese populations. Castellanos *et al.*[15] demonstrated increased gaze duration and gaze direction towards high energy-dense foods (e.g. chocolate and pizza) as compared with low energy-dense foods (e.g. fruit and vegetables) regardless of participants' weight status or hunger condition. This is in contrast to the work of Graham *et al.*[29] who observed enhanced initial

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attentional orientation to high energy-dense sweet food images in females with a low BMI (ranging from 18·1 to 24·9 kg/m^2) as compared with those with a high BMI (ranging from 25 to >30 kg/m^2).

From the few studies that have investigated the potential role that energy density of food images may have in attentional processing of visual food cues in normal weight *v.* over/weight/obese populations; it appears that high energy-dense foods may receive greater selective attention than low energy-dense foods. This may be of particular concern in relation to the development and maintenance of obesity given the association between consumption of high energy-dense foods and subsequent weight gain[46–48]. These findings also reflect results from recent neuroimaging studies[49–53] that demonstrated greater activation of reward pathways in the brain on exposure to high energy-dense food images. Coupled with attentional bias studies, these neuroimaging studies provide a further insight into how eating behaviours may be affected by potential dysregulation in areas of the brain involved in processing the rewarding properties of foods. As high energy-dense foods tend to be heavily represented within our visual environment[54] further research is required to clarify the potential link between increased visual attention to food-related visual stimuli and the energy density of visual food cues, in particular those high in fat and/or sugar and whether this differs in normal weight as compared with an overweight and obese population.

Effects of individual eating style traits

As previously discussed, several studies have considered the impact of weight status on attentional processing of food-related visual stimuli[15,23–29]; however, there has been considerable variation in the methodologies used to conduct these studies and the study populations targeted resulting in varying conclusions being drawn. It has been suggested that although attentional bias to food images may be greater in an overweight/obese population[15,28] there may be subgroups of individuals that have greater selective attention to their food-related environment due to particular eating style traits. For example, previous studies have demonstrated enhanced food-related attentional processing in individuals with higher levels of self-reported external eating[6,55,56] and higher levels of restraint[57,58]. External eating is considered as eating in response to food-related stimuli, for example the sight or smell of food regardless of the internal state of hunger or satiety[59,60]. Restrained eating is considered as a tendency for an individual to restrict food intake to achieve weight loss or to prevent weight gain; however, constant excessive restriction may have the opposite effect resulting in overconsumption of foods and subsequent weight gain[61].

Some recent studies investigating potential weight group differences in attentional processing of visual food stimuli have taken these particular eating style traits into consideration. For example, Nijs *et al.*[23] examined potential weight group differences (normal weight *v.* obese) in the attentional processing of high energy-dense food words using a modified Stroop task and found a significant positive correlation between reaction times and external eating; however, this was only observed in obese participants. Nijs *et al.*[27] also took into consideration eating style traits while investigating attentional processing of food images in a cohort of normal weight and overweight/obese women using a visual probe task, reporting a positive correlation between initial attention to food images and self-reported levels of dietary restraint. Interestingly, Graham *et al.*[29] reported a significant negative correlation between restrained eating scores and initial gaze fixation to food images considered to be high in sugar in a group of overweight/obese females. Castellanos *et al.*[15] found a significant positive correlation between initial attention to food images and both external and restrained eating scores using eye-tracking as a measure of attentional bias in a group of normal weight and obese women. These results indicate that it may be differences in individual eating style traits within a study cohort that may be influencing attentional bias to food-related images either in combination with increasing weight status or as a factor in itself. It may therefore be useful for future studies to employ eating style trait scales such as the Dutch Eating Behaviour Questionnaire[62] to measure levels of restrained and external eating within study cohorts to allow for useful comparison with previously conducted studies.

The study population targeted

Studies assessing visual attention to food-related stimuli as highlighted within this review have targeted both normal weight, overweight and obese individuals. It has been suggested however that enhanced attention to foods through activation of reward-related pathways in the brain may be specific to obese individuals as compared with those who are overweight[27,29] and indicates future studies are required perhaps specifically targeting obese individuals to establish whether a linear relationship could be observed between increasing attentional bias to visual food cues and increasing BMI.

Finally, it is also evident that in the majority of studies, males have been largely underrepresented and research has failed to take into consideration potential weight group differences in the attentional processing of food-related visual cues within a male population. Within this review, only three studies have included male participants[23–25], in which attention to food stimuli was measured using an indirect method. It may therefore be of interest for future studies to include male participants and in particular, studies are required using a direct method of assessing attentional bias such as eye-tracking to provide data on visual attention to food stimuli within an overweight/obese male population.

Conclusions

Overall it appears that results of investigating potential weight group differences in the attentional processing of food-related stimuli are both varied and contradictory.

This may be explained by different methodologies used to measure attention, methods used to measure hunger levels and/or induce satiety, the energy density of food-related stimuli used and stimuli presentation time and also the weight status of the study population targeted. It may be too early to identify definitive patterns in increased attentional bias to foods in overweight and/or obese individuals and furthermore a potential approach-avoidance pattern may also need further exploration with the suggestion that with increasing BMI, comes an attempt to reduce attentional allocation to food-related stimuli as a means to control feelings of cravings. Although attentional bias research with regards to food-related stimuli presents challenges in relation to the most effective study design to successfully assess weight group differences, it is of importance to further understand the complex cognitive processes and attentional mechanisms, in particular the interplay between weight status, state of satiation, eating style traits and energy density of visual food cues that may be impacting on food behaviours and choices related to the development and maintenance of obesity.

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Conflicts of Interest

None.

Authorship

K. J. D. drafted the outline of the review, conducted the literature search and drafted the manuscript. A. M. G., G. D. and D. H. were responsible for critically reviewing and approving the final version of the manuscript.

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