Attentional biases for food cues in overweight and obese individuals: A systematic review of the literature

Hendrikse, J.J., Cachia, R. L, Kothe, E. J., McPhie, S., Skouteris, H., & Hayden, M.J.*

School of Psychology, Deakin University

No authors report any conflict of interest

* Corresponding author:

Melissa Hayden

School of Psychology, Deakin University

221 Burwood Highway, Burwood, 3125

Email: m.hayden@deakin.edu.au

Ph: +613 92443001

Abstract

Background

Obesity rates have increased dramatically in recent decades, and it has proven difficult to treat. An attentional bias towards food cues may be implicated in the aetiology of obesity and influence cravings and food consumption. This review systematically investigated whether attentional biases to food cues exist in overweight/obese compared to healthy weight individuals.

Method

Electronic database were searched for relevant articles from inception to October 2014. Only studies reporting food-related attentional bias between either overweight (BMI 25.0-29.9 kg/m^2) or obese (BMI ≥30) participants and healthy weight participants (BMI 18.5-24.9) were included.

Results

The findings of 19 studies were reported in this review. Results of the literature are suggestive of differences in attentional bias, with all but 4 studies supporting the notion of enhanced reactivity to food stimuli in overweight and obese individuals. This support for attentional bias was observed primarily in studies that employed psychophysiological techniques (i.e. EEG, eye-tracking and fMRI).

Conclusion

Despite the heterogeneous methodology within the featured studies, all measures of attentional bias demonstrated altered cue-reactivity in obese individuals. Considering the theorised implications of attentional biases on obesity pathology, researchers are encouraged to replicate flagship studies to strengthen these inferences.

Introduction

Obesity rates have increased dramatically in recent decades, with more than a tenth of the world's population now classified as obese (1). While the cause of increased weight gain appears straightforward, that is, consuming more calories than energy expended, the reasons why many people are unable to resist eating high calorie, energy dense foods resulting in weight gain are yet to be established conclusively. Researchers have proposed that our engrained ability to detect food, coupled with the rapid proliferation of highly salient food information in modern society, may explain this phenomenon (2, 3). Reducing obesity through weight loss is one of the most important health care interventions within our community, with even modest weight loss (>5% body weight) leading to significant health benefits (4). However, obesity has proven to be difficult to both prevent and treat, with less than 3% of individuals who participate in a behavioural weight management program successfully maintaining weight loss (5, 6). It has been suggested that an increased attentional bias to food cues may contribute to overeating and weight gain (7). An attentional bias towards food may help to explain why some individuals fail to respond to weight loss interventions and why some individuals struggle to maintain weight loss following interventions. As such, researchers have argued that an increased understanding of the cognitive and neural mechanisms involved in the regulation of eating behaviour may aid in the treatment and/or prevention of this complex global health problem (8, 9).

The potential role of attentional bias in obesity was identified as early as 1971 when Schacter noted that obese individuals were hypersensitive to and 'more efficient information processors' of environmental food stimuli than healthy weight individuals (10). More recently the Dual Process model (e.g. 11) has proposed that two higher order processes are implicated in the modulation of behaviours such as food consumption: an attentional bias towards foods cues and a deficit in self-control leading to an inability to resist tempting foods (12-14). Analysis of these two processes also illustrates the antagonistic relationship between reward-driven ‘hedonic feeding’ (the tendency to eat in excess of dietary energy requirements) and indices of feeding inhibition (the ability to exert top-down control over appetitive motivational processes) (15).

There is a contemporary body of research conceptualising food-related pathology as a type of addiction (12, 13). Recent studies have reported physiological and cognitive similarities between those suffering from uncontrolled food consumption and other forms of addiction, such as nicotine, alcohol and opioid dependence (12). Predominating models of addiction assert that the repeated pairing of a salient cue (in this case food related) and a rewarding outcome creates a hypersensitisation of the dopaminergic reward system, reciprocally increasing the ‘attention-grabbing’ property of the stimuli (16). This leads to a mutually excitatory relationship between craving and substance use (i.e., excessive food consumption). Individuals who automatically detect and devote increased attention to food-related information are thought of as being prone to overeating and at an increased risk of obesity (12). Similarly, obese individuals are believed to display an enhanced sensitivity in favour of food relevant stimuli as a result of this associative conditioned mechanism. This aberrant attentional processing leads obese individuals to become ‘more efficient stimulus processors’ of environmental food information (3).

Recent neuroimaging literature has shown evidence of differences in these processes between obese and healthy weight individuals. Specifically, studies that have compared obese individuals to healthy weight controls have shown that obese individuals demonstrate heightened food cue-reactivity and altered levels of neural reward circuitry activation and connectivity (17-19). An exaggerated salience of food information and associated hyperactivity in reward centres may override homeostatic control mechanisms in obese individuals (8).

The current review explores the role of attentional bias in obesity. In their 2012 review Nijs and Franken suggested that there is an approach avoidance pattern of attention in overweight/obese individuals and that increased knowledge of these systems could help improve the current treatment programs available (20). Although that review considered the relationship between attentional processing of food cues in obese and overweight individuals (20) it only considered research published from 2009 – 2011 and a systematic search of literature was not conducted. Given the long history of research within this domain and the rapid advancement in research methodology within the last decade, a more comprehensive and up-to-date review is warranted. This paper builds on previous work in this field in order to systematically investigate whether or not attentional biases to food cues exist in overweight/obese compared to healthy weight individuals.

Method

Eligibility Criteria

Papers were eligible if they reported food-related attentional bias between either overweight (BMI 25.0-29.9 kg/m^2) or obese (BMI ≥30) participants and healthy weight participants (BMI 18.5-24.9). The analysis of BMI as either a continuous or categorical variable was accepted. Only empirical studies were included. All studies were in English, human studies, peer-reviewed, and published between inception and October 2014.

Information Sources and Study Selection

Studies were identified through electronic database searches of Academic Search Complete, Psychology and Behavioural Sciences Collection, PsycINFO, PsycARTICLES, MEDLINE Complete, Global Health and CINAHL conducted through EBSCO host, and EMBASE. The date of the last search was the 15th of October 2014. Search terms included obesity, (obes*, overweight*, body mass index, BMI, overeat*, binge eat*, bariatric*, disordered eat*, food intake, weight loss) and attentional bias (attention* bias*, cogniti* bias*, information* bias*, information* process*, self regulat*, executive function*, reward* sensitiv*, concentrat* bias*, cue reactiv*).

After the removal of duplicates the title and abstracts were screened for eligibility by two authors (RC & JH). The full texts of eligible studies were assessed and identified (RC & JH), facilitated through the use of a relevance assessment tool. The relevance tool was a simple checklist ensuring that each paper, a) included an obese or overweight/obese sample with a healthy weight control group, b) included a measure of attentional bias, c) was an empirical study (not a review), and d) was a human study published in English. In addition, reference lists of included studies and similar reviews were searched for relevant studies. Consultation amongst all authors resolved the eligibility of questionable papers.

Data extraction

Data were extracted from papers by entering the information intro a matrix incorporating the variable of interest including: participant characteristics, sample size, study design, measure, stimuli and results of each study.

Results

Study Selection

After the removal of duplicates, the initial search produced 1,499 citations. 1,168 were excluded, leaving 331 citations to be examined in more detail. Nineteen papers were deemed relevant for the current review; 7 of these papers (2, 3, 12-14, 21, 22) were also included in the review by Nijs and Franken (20). Figure 1 outlines the flow of studies included in the review.

Study Characteristics

Participant characteristics, sample size, study design, measure, stimuli and results of each study are presented in Table 1. Three studies contained an adolescent sample (23-25) whilst the remaining 16 studies contained an adult sample.

BMI was self-reported in four studies (3, 12, 26, 27), and participants' heights and weights objectively measured in six studies (2, 14, 19, 21, 24, 28). There were seven studies in which measurements of weight and height were unspecified (9, 13, 17, 22, 25, 29, 30). In studies featuring an adolescent sample, two studies (24, 25) calculated BMI using the Center for Disease Control and

Prevention (CDC) BMI-for-age growth chart (31), whilst one study employed the weight for height method as recommended by the World Health Organisation (23).

Seven studies consisted of a female only sample (2, 12, 14, 21, 24, 26, 28), with a further three including a sample with a higher proportion of females than males (3, 13, 29). Ten studies were conducted in Europe and nine studies were conducted in the U.S.A (see Table 1).

A broad range of cognitive tasks were employed across the studies in the current review including; the modified food-Stroop Task (3, 22, 23), Visual Dot Probe Tasks (VDP) (2, 13, 14, 21, 24, 26, 28, 29), the attentional network task (ANT) (24) and one-back visual recognition tasks (9). Other studies utilised paradigms of passive-picture presentation, either in a paired format (12) or in a randomised-blocked format (17-19, 25, 30). The Go-no/go Task was also included in one study (13). However, this task was intended as a measure of inhibitory control and is therefore not reported within the findings. Similarly, across the featured literature a variety of experimental methodologies were used. This included electroencephalography with investigation of various Event Related Potentials (ERP's) (3, 21, 27), eye-tracking (ET) (2, 12, 14, 21) and functional Magnetic Resonance Imaging (fMRI) (9, 17-19, 24, 25, 29, 30). Table 1 displays the results of the current literature by experimental task.

Visual dot probe task (VDP).

Five out of the seven studies employing the VDP task indicate significant differences in attentional bias between obese and healthy weight individuals in response to food stimuli (2, 13, 14, 21, 28, 29). Overweight/obese participants responded more slowly to both food and neutral stimuli than healthy weight participants (21, 28, 29) and obese individuals also responded more rapidly to probes replacing high calorie food words than control stimuli (28). Castellanos et al. (2) and Werthmann et al. (14) showed enhanced initial orientation to food stimuli, as measured through eye-tracking, in satiated and obese individuals who fasted for two hours prior to testing, respectively. These findings overwhelmingly suggest that despite different task methodologies, utilisation of the VDP tasks provides consistent evidence of an attentional bias towards food in obese individuals. Only two studies (26) and Loeber (13) did not report any significant associations.

Food Attention Network Test (ANT)

One study utilised the food ANT to measure attentional bias (24). The ANT is designed to assess alerting, orienting, and executive control networks (32). Yokum, Ng and Stice (24) reported a positive correlation between BMI and response time to food stimuli. fMRI findings also reported a positive correlation between BMI and activation of brain regions related to attention and food reward (anterior insula/frontal operculum, ventrolateral prefrontal cortex) during exposure to pictorial food stimuli.

Food-modified Stroop task

Two of the three studies employing the food-modified Stroop task demonstrated altered attentional biases to food information between weight groups (3, 23). Braet and colleagues (23) reported significantly delayed response times and Stroop-interference effects in obese adolescents to food stimuli, as compared to healthy weight controls. Using EEG, Nijs, Franken and Muris (3) reported no significant differences between weight groups for Stroop reaction times nor P300 amplitudes, however reported P200 amplitude was greater in the obese group in response to food stimuli. Phelan and colleagues (22) reported no significant between group differences.

One-back visual recognition task

The one-back visual recognition task was included in one study (9). This task, an implicit measure of attentional bias, was used in conjunction with fMRI. Kullman (9) found no significant between-group reaction time differences on the one-back task. However, by means of independent component analysis a dissociable pattern of activation in two visual networks and the salience network between weight groups was found in response to food stimuli. Thus, altered functional connectivity in these systems was shown as a function of stimulus category (food versus non-food images), calorie content (high calorie food images versus low calorie food images) and weight group (obese versus healthy weight). These findings were taken to suggest heightened attention and a generalised augmented response to food stimuli in overweight/obese subjects, perhaps contributing to top-down deficiencies.

<u>Passive picture presentation</u>

Utilising a paired-picture paradigm Graham et al reported variable eye-movement as a function of stimulus category and weight group (12). An enhanced direction bias in the obese weight group to low-calorie stimuli was reported accompanied by decreased pupil diameter in the obese group to high calorie sweet words as compared to low-calorie words. Five studies used a randomised-blocked passive picture presentation and fMRI. Each of these reported significant activation differences between weight groups in striatal regions known to be involved in salience networks and reward processing (17-19, 25, 30). These dissociable patterns of activation suggest that obese individual's attention to food stimuli is significantly augmented, relative to those of a healthy weight range.

Discussion

Summary of Evidence

The present review outlines 19 studies investigating attentional bias in obese individuals. Overall, results of the literature are suggestive of differences in attentional bias to food information between obese and healthy weight individuals. Support for attentional bias was strong with all but four studies supporting the notion of enhanced reactivity to food stimuli in overweight and obese individuals (3, 13, 22, 26). This support for an attentional bias was primarily observed at the psychophysiological level (eye-tracking bias and increased brain activation as seen by enhanced evoked potentials in EEG and increase brain activation in fMRI). The neuroimaging literature reported altered reward circuitry interactions (18) and variable strengths of cortical connectivity (17, 19, 24, 25, 30, 33) between obese and healthy weight individuals in response to food stimuli. Additionally, cortical volume differences between weight groups were found in two studies (34, 35). Collectively, these results indicate that neural substrates and systems regulating food intake may vary markedly between weight groups, perhaps contributing to pathological overeating and weight gain.

While the use of behavioural and EEG/ET techniques have allowed researchers to explore cognitive processing differences in obese individuals, the inclusion of fMRI data allow for an exploration of the neurocognitive mechanisms origins of this differentiated cognitive processing. Stoeckel (18) demonstrated that reward system activation is not only exaggerated but also atypical in obese individuals. Their study reported a reduced amygdala, OFC, NAc connectivity but an enhanced OFC, NAc connection, leading to a conclusion of a heightened drive for food consumption coupled with an ineffectual modulation of the reward value of food cues in obese individuals. Furthermore, extensive activation differences in regions of interest between obese and healthy weight individuals have been reported by all featured fMRI studies (9, 17-19, 24, 25, 29, 30) . These data suggest that an exaggerated vigilance and hyper-responsiveness to food cues may be pertinent components in obesity. Functional MRI findings, such as those of Rothemund et al. (30) are also congruent with the incentive-sensitization model of addiction, as they demonstrate common neural substrates between obese individuals and other forms of addiction, in addition to decreased DA receptor availability.

Heterogeneity of Results

Attentional biases in obese individuals was reported in the majority (15/19) of the studies included in the current review, even though many different cognitive tasks have been employed and several different neuroscientific methods used. It has been argued that conflicting results may arise through differences in task demands (e.g VDP compared to Stroop) and that different measures may in fact tap into a range of different attentional constructs (12, 20). For example, explicit attentional involvement in the VDP may draw from different attentional indices compared to passive 'free-viewing' paradigms (12). While there is debate as to the specific index of informational processing these tasks draw from, their efficacy in determining significant attentional differences has been paramount in furthering researchers' knowledge.

Strengths and Limitations of this Review

This review provides a novel contribution to existing research in this field. The breadth of investigative approach within the literature facilitated an acute analysis, allowing a comparison of the ways in which different techniques may elicit divergent findings. The inclusion of all methods of cognitive neuroscience (i.e. not excluding fMRI studies) allowed for comparison of both temporal and spatial data.

Limitations of the included studies

The heterogeneous methodology of research in this field creates several limitations. As previously mentioned, the range of investigative techniques available to researchers creates difficulties for the comparability of findings (12). In addition, sample characteristics may be an important source of variance in findings. In particular, the studies included in this review included a wide range of BMIs within obese weight groups. Werthmann et al. (14) noted that BMI ranges might be implicated in inconsistent results. Their sample of overweight/obese participants (BMI: M=28.03, SD=3.74, Range=25.09-40.04) failed to show maintained attention using eye-tracking, whereas in a similar study by Castellanos et al. (2) a significant maintained attentional bias in both fasted and satiated states in a sample of obese participants of a higher average BMI is reported (M= 38.69, SD of 6.87, Range= 30.02-52.32). It is possible that the differences in BMI between studies may be linked to the differences in attention allocation. Similarly, the majority of included studies only contained female participants, or contained an unequal ratio of female to male participants. The effects of gender differences in attention research remain largely unresolved and unclarified, and thus have not been adequately controlled for across attentional bias literature (23).

Conclusion

Fifteen out of the 19 studies featured in this review support the notion of enhanced attentional biases to food stimuli in obese individuals. Whilst breadth in experimental approach may have an effect on the consistency and replicability of results, only four of the featured studies failed to show differences in attentional bias to food stimuli by factor of weight (13, 22, 26, 27). In classifying the featured literature by experimental task (as shown in Table 1) it is evident that the use of all measures demonstrated altered cue-reactivity in obese individuals. Considering the theorised implications of attentional biases on the aetiology of obesity, future research may strengthen these inferences and aim to replicate flagship studies, such as that by Nijs and colleagues (3).

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Figure 1. Flow diagram of study selection.

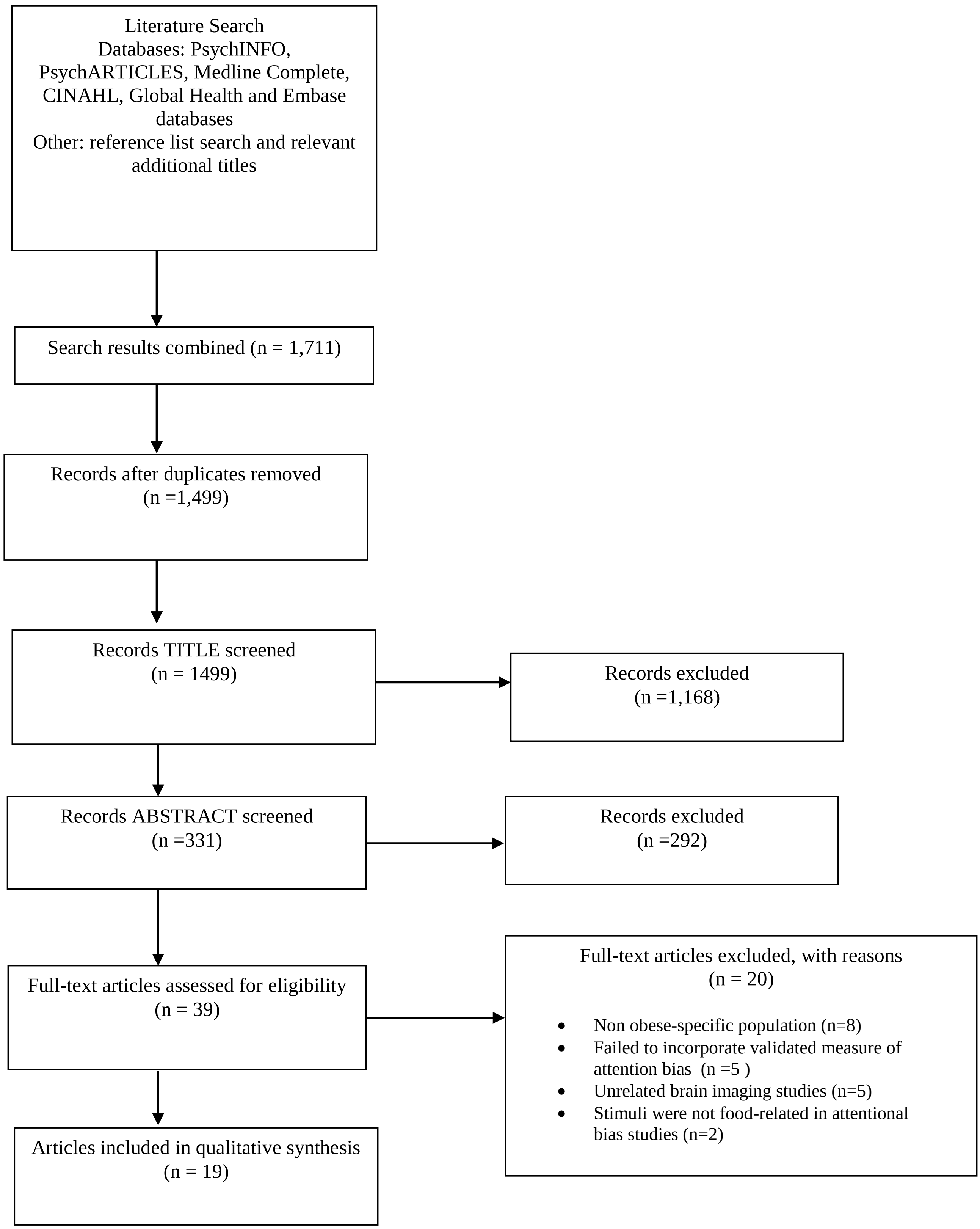

Table 1
A Summary of Attentional Bias Studies

Experimental Task	Study	Sample	Measure	Stimuli	Main Findings: Difference OW/OB and HW Subjects
Visual Dot Probe					
	Ahern et. al., 2010 (UK)	Students (F=100%) HW+OW+OB = 63 (M BMI = 22.8±0.4, BMI range = 17.9-33.4, M age = 20.2±0.3)	RT	30 picture pairs: HC/LC food and non-food pictures	BMI and RT did not correlate; All participants had faster RT when the probe replaced food-related stimuli.
	Castellanos et. al., 2009 (USA)	Adults (F=100%) 18 HW (M BMI= 21.73±1.85, M age = 27.91±3.45) & 18 OB (M BMI = 38.69±6.87, M age = 29.50±4.48)	RT ET duration bias, ET direction bias,	60 pictures: 20 HC food, 20 LC food and 20 scenery pictures	RT: No difference between OW and HW ET duration + direction bias: Hungry: No difference between OW and NW. Satiated: OB > HW

García-García et. al., 2012 (Spain)	Adults (F = 64%) 19 HW (M BMI = 22.44±1.93, M age = 32.0±5.87) & 15 OW/OB (M BMI = 34.89±4.78, M age = 34.78±4.45)	RT fMRI	32 HC and 32 LC food pictures paired with 32 neutral and 32 rewarding non-food pictures	RT: OB/HW both slower RT in HC food and rewarding non-food stimuli. fMRI: OB decreased activation in bilateral activation of occipital lobe, lateral prefrontal cortex, medial prefrontal cortex, precentral gyrus, paracingulate gyrus and anterior cingulate gyrus, precuneous, posterior cingulate cortex and lateral occipital cortex.
Kemps et. al., 2014 (Australia)	Adults (F=100%) 58 HW (BMI 18.5-24.9) & 58 OB (BMI ≥ 30, M age= 44.38±11.92)	RT	10 HC, 10 LC food words and 60 animal words.	Overall RT: OB slower to respond to probe position than HW OB faster RT to probes replacing food words than animal words. OB faster RT to probes replacing HC food words than animal words. HW no difference in RT to different probes.
Loeber et. al., 2012 (Germany)	Adults (F = 65%) 20 HW (M BMI = 22.6±1.1, M age = 44.9±11.7) & 20 OB (M BMI = 38.8±6.3, M age = 47.9±12.5)	RT	80 pictures: 20 food-associated, 20 objects and 40 neutral pictures	No RT difference between OB and HW in response to food stimuli.

	Nijs et al., 2010b (Netherlands)	Adults (F = 100%) 40 HW (M BMI = 20.63±1.14, M age = 20.63±1.14) & 26 OW/OB (M BMI = 30±4.62, M age = 21.5±3.36)	RT P300 ERP ET	15 picture pairs: HC food and neutral office items	RT: OW slower than HW to both food and non-food stimuli ET: No significant differences P300: No significant differences between groups
	Werthmann et. al., 2011 (Netherlands)	Adults (F = 100%) 29 HW (M BMI = 21.16±2.03, M age = 19.31±1.95) & 22 OB (M BMI = 28.03±3.74, M age = 19.86±1.28)	RT ET direction bias, ET duration bias, ET dwell time bias	20 picture pairs: HC food pictures and control pictures of musical instruments	RT: no difference between groups Direction bias: OB > HW to food stimuli. Duration bias: NW > OB to food stimuli. Dwell time bias: No difference between groups.
Modified Food Stroop					
	Braet & Crombez, 2003 (Belgium)	Children 9 –16 years (F =71%) 40 HW (103% ± 13, M age 13.9±2.0) & 34 OB (177% ± 24, M age 13.3±2.0 &	RT	20 food words, 20 negative emotion words & 40 control words	Overall Stroop RT: OW slower than HW. Stroop RT interference food stimuli: OW slower than HW.

	Nijs, et al., 2010a (Netherlands)	Adults (F= 80%) 20 HW (M BMI = 22.68±1.53, M age = 28.65±6.08) & 20 OB (M BMI = 36.69±6.47, M age = 28.65±6.59)	RT ERP: P200, P300	40 pictures: 20 HC food and 20 pictures of office items	RT: No difference between OB and HW P200 ERP: larger amplitude in OB compared to HW in response to food stimuli P300 ERP: No difference between groups in response to food stimuli
	Phelan et. al., 2011 (USA)	Adults (F=86%) 19 HW (M BMI = 21.6± 2.0, M age = 43.6± 8.2) & 14 OB (M BMI = 34.3±6.7, M age = 48.3±7.6) & 15 WLM (M BMI = 23.7±1.6, M age = 48.5±11.4)	RT errors	Neutral non-food words, HC food and LC food words (printed in either red, blue or green ink)	RT: No significant difference between HW and OB
Passive Picture Pairs					
Presentation of food pair pictures - passive	Graham et. al., 2011 (USA)	University Students (F = 100%) 21 UN/HW (M BMI = 21.3±2.3, M age = 21.0±3.0) &15 OB (M BMI = 28.9±5.0, M age = 23.4±5.5)	ET duration bias, ET direction bias, Pupil diameter	60 paired food pictures: 20 HC sweet foods, 20 HC savoury foods and 20 LC foods	Direction bias: OB > HW to LC food stimuli. Duration bias: No difference between groups. Pupil diameter: decreased in OB to HC sweet words compared to LC words

Randomised-blocked passive picture presentation/viewing					
	Davids et. al., 2009 (Germany)	Adolescents 9-18 years (F = 61 %) 22 HW (M BMI =19.70±2.50, M age = 13.54±2.9) & 22 OB (M BMI = 29.44±2.32, M age = 13.49±2.3)	fMRI	60 pictures: 20 Food, 20 ‘pleasant’ positive valanced and 20 non-food pictures	OB higher activation of dlPFC to food images than HW. HW higher activation of caudate and hippocampus to food pictures than OB
	Nijs et al., 2008 (Netherlands)	Adults (F= 80%) 20 HW (M BMI = 22.68±1.53, M age = 28.65±6.08) & 20 OB (M BMI = 36.69±6.47, M age = 28.65±6.59)	ERP: P300, LPP	40 pictures: 20 HC food and 20 control pictures of office items	ERP amplitude: No difference between OB and HW in response to food stimuli
	Rothemund et. al., 2007 (Germany)	Adults (F=100%) 13 HW (M BMI = 20.9±1.7, M age = 29±5.6) & 13 OB (M BMI = 36.3±4.8, M age = 31±9.4)	fMRI	40 pictures: high calorie, low calorie and neutral (utensil) items	OB show greater activation of the dorsal striatum and anterior insula, claustrum, posterior cingulate and postcentral lateral orbitofrontal cortex than HW

	Scharmuller et. al., 2012 (Austria)	Adults (F=100%) 14 HW (M BMI = 20.6±1.3, M age = 25.6±6.7) & 12 OB (M BMI =31.5±5.2, M age = 26.6±4.5)	fMRI	60 pictures: 30 Food and 30 neutral non-food items (geometric shapes)	OB increased activation of insula and medial OFC than HW in response to food cues. OB increased DLPFC activation than HW in attenuation paradigm
	Stoeckel et. al., 2008 (USA)	Adult (F=100%) 12 HW (BMI 19.7-24.5) and 12 OB (BMI 30.8-41.2)*	fMRI	256 pictures: 84 HC, 84 LC, and control "car" images	OB increased activation in medial and lateral OFC, amygdala, NA, mPFC, insula, ACC, ventral pallidum, caudate, putamen and hippocampus compared to HW
	Stoeckel et. al., 2009 (USA)	Adult (F=100%) 12 HW (BMI 19.7-24.5) and 12 OB (BMI 30.8-41.2)*	fMRI	256 pictures: 84 HC, 84 LC, and control "car" images	OB greater left hemisphere OFC-NAc connectivity than HW. Reduced connectivity from Amygdala to OFC and NAc in OB compared to HW
One-back visual recognition task	Kullman et. al., 2013 (Germany)	Adults (F= 50%) 12 HW (M BMI = 21.16± 1.13, M age = 22.91±2.10) 3 OW & 9 OB (M BMI = 30.46±1.77, M age 24.66±2.42)	RT fMRI	96 pictures: 48 HC/LC and 48 non-food control images	RT: No significant difference between HW and OB Extensive modulation elicited by food stimuli in 2 visual and salience networks with significant differences between OB and HW. OB generalised augmented activation of salience network relative to HW.

Food Attention Network Test (ANT)	Yokum et. al., 2011 (USA)	Adolescents (F=100%) HW+OW+OB =39 (M BMI = 24.2±4.5, BMI range 17.3-38.8, M age = 15.6±0.96).	RT fMRI	20 picture pairs: appetizing and non-appetizing food pictures, neutral 'glass of water' control stimuli.	RT: positive correlation between BMI and response time to appetizing and non-appetizing food stimuli, but not control stimuli. Positive correlation between BMI and activation in anterior insula/frontal operculum lateral OFC, vlPFC and superior parietal lobe during initial orientation to food cues

Note. BMI body mass index; dlPFC dorsolateral pre-frontal cortex; ET eye-tracking; EMT explicit memory task; ERP event-related potentials; fMRI functional magnetic resonance imagining; HC high calorie; IMT implicit memory task; IWT imbedded word task; LC low calorie; M mean; mPFC medial prefrontal cortex; NAc nucleus accumbens; UN underweight; HW healthy weight; OB obese; OFC orbitofrontal cortex; OW overweight; RT reaction time; vlPFC ventrolateral prefrontal cortex

*age not specified