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Biased Attentional Processing of Food Cues and Modification in Obese Individuals

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Abstract

Objective: This paper reports two experiments designed to investigate and modify biased attentional processing of food cues in obesity. **Experiment 1:** Experiment 1 used a dot probe task to show a food-related attentional bias in 58 obese women, relative to a comparison sample of normal weight controls. **Experiment 2:** Experiment 2 examined whether this bias can be modified. Using a modified dot probe task, 96 obese women were trained to attend to, or to avoid, food pictures. Attentional bias for food increased in the attend group, and decreased in the avoid group. The attentional re-training effects generalised to an independent measure of biased information processing, such that participants in the avoid group produced relatively fewer food than animal words on a subsequent word stem completion task than those in the attend group. **Conclusion:** The results extend the application of attentional bias modification from anxiety and addiction to obesity. They also offer potential scope for tackling pathological (over)eating.

Keywords: food cues, obesity, attentional bias, dot probe task, cognitive bias modification

Biased Attentional Processing of Food Cues and Modification in Obese Individuals

It is estimated that globally more than half a billion adults are obese, a figure that has nearly doubled over the past three decades (World Health Organisation, 2013). An acknowledged important contributor to the continuing increase in obesity rates in modern industrialised societies is an "obesogenic" environment – an environment in which densely calorific food is readily available and physical demands are low (Novak & Brownell, 2011). One notable aspect of this environment is the continual exposure to food cues, not only in shops, restaurants and fast food outlets, but also through advertising in magazines and on television.

As early as the 1970s, Rodin and colleagues (Rodin, 1976; Rodin, Slochower & Fleming, 1977; Schachter & Rodin, 1974) noted that, compared to people of normal weight, obese individuals may be more responsive to environmental food cues. While not all studies in the subsequent three decades have found a difference between obese and normal weight individuals in response to external food cues (e.g., Nisbett & Temoshok, 1976; van Strien & Ouwens, 2003), many have confirmed Rodin's initial finding (e.g., Burton, Smit and Lightowler, 2007). More recent theoretical accounts have attributed the heightened responsiveness to food cues among the obese to (1) the activation of dysfunctional knowledge structures (i.e., schemas) which reflect an over-concern with food and eating (Cox & Klinger, 2004; Williamson et al., 2004), or (2) an excessive release of dopamine in the brain's reward system which serves to increase the reinforcing value (i.e., incentive salience) of food (Berridge, Ho, Jocelyn & DiFeliceantonio, 2010; Volkow & Wise, 2005). Common to these theoretical perspectives is the prediction that obese individuals selectively attend to food and eating stimuli, that is, they show an attentional bias for such stimuli.

Attentional biases have also been shown for other consumption behaviours, such as smoking and drinking, as well as broader health behaviours, such as physical activity and sleep. Thus, smokers selectively attend to smoking cues (Waters, Shiffman, Bradley & Mogg, 2003), while heavy drinkers do so for alcohol cues (Townshend & Duka, 2001). Likewise, non-exercisers pay more attention to sedentary than physical activity cues (Berry, 2006), and insomnia patients preferentially attend to sleep-related stimuli (Jones, McPhee, Broomfield, Jones & Espie, 2005). These biases are thought to contribute to the development and maintenance of the particular behaviour.

The tendency to selectively attend to food (or other) stimuli is thought to occur automatically, without necessary conscious awareness, and hence needs to be assessed by implicit processing measures. Biased attentional processing of food and eating-related information in obese adults and children has been demonstrated using a range of implicit measures, including the modified Stroop task, the dot probe task, eye movement tracking and event-related potentials (Braet & Crombez, 2003; Castellanos et al., 2009; Graham, Hoover, Ceballos & Komogrotsev, 2011; Nijs, Franken & Muris, 2010a; Nijs, Muris, Euser & Franken, 2010b; Long, Hinton & Gillespie, 1994; Wertheim et al., 2011). However, not all studies have found an attentional bias for food cues in obese participants (Phelan et al., 2011), and some studies have observed a bias using one measure but not another (Castellanos et al., 2009; Nijs et al., 2010a,b; Wertheim et al., 2011). Small sample sizes and methodological variations between studies, such as the inclusion of overweight but not obese individuals, and testing participants under fasted or sated conditions could account for these inconsistent findings.

Recent investigations have linked attentional bias for food cues to future weight gain. For example, Calitri, Pothos, Tapper, Brunstrom and Rogers (2010) showed that attentional bias for unhealthy food predicted an increase in body mass index (BMI) one year later. Furthermore, Yokum, Ng and Stice (2011) reported that greater activation of the orbitofrontal cortex (a brain region involved in regulating reward) during initial orientation to appetising food images correlated with increases in BMI at one-year follow-up. These findings suggest that attentional bias for food cues plays a role in the development of overeating and obesity. They also point to attentional processes as a potential target for intervention.

Over the past decade, attentional bias modification has shown promise in the areas of anxiety and substance abuse. In a seminal study, MacLeod, Rutherford, Campbell, Ebsworthy and Holker (2002) developed a modified dot probe paradigm to train anxious individuals to direct their attention away from emotionally threatening cues, and showed that this reduced participants’ attentional bias for such cues. This finding has since been replicated (for a review, see Hertel & Mathews, 2011) and extended to addictive substances, in particular alcohol and tobacco (for a review, see Wiers, Gladwin, Hofmann, Salemink & Ridderinkhof, 2013). For example, Field and Eastwood (2005) showed that heavy social drinkers who were trained to direct their attention away from alcohol-related pictures showed a reduced attentional bias for such pictures. This result has been replicated a number of times (Field et al., 2007; Schoenmakers, Wiers, Jones, Bruce & Jansen, 2007; Schoenmakers et al., 2010). Similarly, studies have shown that training cigarette smokers to avoid smoking-related stimuli made them less attentive to these stimuli (Attwood, O’Sullivan, Leonards, Mackintosh & Mufano, 2008; Field, Duka, Tyler & Schoenmakers, 2009).

It is argued that attentional bias modification changes maladaptive biased stimulus processing by giving repeated practice at avoiding attention to disorder-related stimulus cues (Koster, Fox & MacLeod, 2009). Specifically, in the modified dot probe task, the most widely used attentional bias modification procedure, two stimuli (one disorder-related, one neutral) appear simultaneously on the computer screen, followed by a probe (usually a dot) in the previous location of one or the other stimulus. Participants are required to respond as quickly as possible to the location of the probe. In the original assessment version of the task, probes replace disorder-related and neutral stimuli equally often. The modified version introduces a contingency such that in one group probes disproportionately replace disorder-related stimuli (to increase attentional bias), while in the other group probes replace neutral stimuli (to reduce attentional bias). Participants are instructed to focus on the ostensibly unrelated task of responding to probe location. Thus attentional bias modification involves an implicit learning process whereby the attentional bias gradually shifts toward or away from disorder-relevant cues.

To our knowledge, attentional bias modification has not yet been demonstrated for food in general in any sample; however, a recent paper demonstrated such modification for chocolate cues in an undergraduate sample of normal weight individuals (Kemps, Tiggemann, Orr & Grear, in press). Thus this study represents the first attempt to modify attentional bias for food cues in general, and importantly, in a sample of obese participants. The overall aim of the present experiments was to investigate biased attentional processing of food cues, and its modification, in obese individuals, for whom exposure to environmental food cues are likely to be particularly problematic. Experiment 1 examined attentional bias for food stimuli in a larger sample of obese women than in previous studies, relative to a comparison group of normal weight controls. Consistent with research on attentional bias in other domains, we used the dot probe task to assess attentional bias for food cues. Experiment 2 subsequently used a modified dot probe task to investigate whether attentional bias for food cues in obese individuals can be modified. The experiments were approved by the Social and Behavioural Research Ethics Committee.

Experiment 1

Method

Participants. Participants were 116 healthy community-dwelling women, 58 of whom were obese (BMI ≥ 30 kg/m^2) and 58 of normal weight (BMI in the range 18.5 to 24.9 kg/m^2). Only women were included as some studies have reported gender differences in cognitive biases for food in obese samples (e.g., Havermans, Giesen, Houben & Jansen, 2011). Participants were between 18 and 64 years old (*M* = 44.38, *SD* = 11.92), and spoke English as their first language. Participants were recruited from the Adelaide metropolitan area via an advertisement in the local newspaper, and received a $20 honorarium. As hunger has been linked to attentional biases for food (Mogg, Bradley, Hyare & Lee, 1998), and fasting has been shown to exacerbate such biases in obese individuals (Nijs et al., 2010b), participants were instructed to eat something two hours before the testing session to ensure they were not hungry. All participants reported having complied with this instruction. Additionally, participants rated their level of hunger on a 100-mm visual analogue scale, ranging from “not hungry at all” to “extremely hungry”. Hunger ratings were relatively low, and did not differ between groups (obese: *M* = 26.30, *SD* = 23.87; normal weight: *M* = 27.10, *SD* = 24.93), *t*(114) = .18, *p* > .05. Furthermore, all participants reported that they ate and liked most foods, and were not vegetarian.

Materials.

Dot probe task. The stimuli were 20 food words and 60 animal words. Animals were chosen as the non-food control category, because like food, this semantic category is overall appealing. The food words consisted of 10 high caloric (e.g., cake, pizza) and 10 low caloric (e.g., salad, yoghurt) food items. The animal words included animal species that are generally well-liked and are not commonly consumed in Western cultures (e.g., kitten, platypus). Two categories of word pairs were constructed: critical (food – animal) and control (animal – animal), with 20 word pairs per category. The words of each pair were individually matched for number of letters and syllables, as well as ratings of valence and arousal. These ratings were obtained on the basis of a pilot study in which 19 women aged 18 to 24 years (*M* = 21.05, *SD* = 1.35) rated 181 food and animal words on 9-point valence and arousal scales.

Another 14 word pairs, comprising stationery items (e.g., pencil, stapler) were created for practice and buffer trials.

On each trial of the task, a fixation cross was displayed in the centre of the screen for 500 ms, followed by the presentation of a word pair for 500 ms. The words were presented in lower case, black, 12 mm high, Arial font on a white background. They appeared one above the other, centred horizontally and equidistant (i.e., 40 mm) from the centre of the screen. A dot probe was then displayed in the location of one of the previously presented words. Participants were asked to indicate as quickly as possible whether the dot probe appeared in the location previously occupied by the upper or the lower word, by pressing the corresponding keys labelled U (‘q’) and L (‘z’) on the computer keyboard. The dot probe remained displayed until a response was made. The inter-trial interval was 500 ms.

The task commenced with 12 practice trials, followed by 2 buffer trials and 160 experimental trials. In the experimental trials, each of the 20 critical (food – animal) word pairs and each of the 20 control (animal – animal) word pairs was presented four times, once for each of the word location (upper or lower) × dot probe location (upper or lower) combinations. Trials were presented in a new randomly chosen order for each participant.

Procedure. Participants were tested individually in a quiet room in the Applied Cognitive Psychology Laboratory at Flinders University in a single session of 30 min. duration. They were seated approximately 50 cm in front of an IBM compatible computer with a 22-inch monitor. After giving informed consent, participants completed a brief demographics questionnaire, followed by the dot probe task. Finally, participants’ height and weight were measured from which body mass index (BMI) was calculated as the ratio of weight in kilograms to height in meters squared.

Results

Statistical considerations. An alpha level of .05 was used to determine significance. Partial η^2 was used as the effect size measure for ANCOVAs; Cohen's *d* was used for t-tests. Benchmarks for partial η^2 are .01, small; .06, medium; .14, large; and for Cohen's *d* .20, small; .50, medium; .80, large.

Attentional bias. As is standard practice, response times of incorrect trials (when participants pressed the wrong response key – 1.3% of data) were discarded. Following previous protocols (e.g., Townshend & Duka, 2001), response times of less than 150 ms or more than 1500 ms were considered anticipatory and delayed respectively, and eliminated as outliers, as were response times more than 3 *SD*s above or below the individual mean. Outliers accounted for 1.2% of the data.

To investigate whether obese individuals showed an attentional bias for food cues, mean reaction times on the critical trials (food – animal pairs) were analysed by a 2 (group: obese, normal weight) × 2 (probe position: probe replaces food versus animal) mixed-design ANOVA. There was a significant main effect of group, $F(1, 114) = 5.56$, $p < .05$, partial $\eta^2 = .05$, whereby the obese individuals ($M = 467$ ms) were overall slower to respond to probes than individuals of normal weight ($M = 440$ ms). There was no main effect of probe position, $F(1, 114) = 1.07$, $p > .05$. Importantly, however, there was a significant group × probe position interaction, $F(1, 114) = 5.07$, $p < .05$, partial $\eta^2 = .04$. As can be seen in Figure 1, paired samples *t* tests showed that the obese participants were faster to respond to probes replacing food words than to probes replacing animal words, $t(57) = 2.22$, $p < .05$, $d = .09$, indicative of an attentional bias for food, whereas the normal weight controls showed no such difference, $t(57) = .91$, $p > .05$.

To investigate whether the obese group showed the attentional bias for both high and low caloric food, separate ANOVAs were conducted for high caloric food – animal pairs and low caloric food – animal pairs (see Figure 2). The analysis of the high caloric food – animal pairs replicated the overall findings. That is, there was a significant main effect of group, $F(1, 114) = 5.18$, $p < .05$, partial $\eta^2 = .04$, but no main effect of probe position, $F(1, 114) = 1.82$, $p > .05$, and again a significant group × probe position interaction, $F(1, 114) = 5.87$, $p < .05$, partial $\eta^2 = .05$, such that obese individuals responded faster to probes replacing high caloric food words than to probes replacing animal words, $t(57) = 2.63$, $p < .05$, $d = .15$. The normal weight controls did not respond differently to these probes, $t(57) = .77$, $p > .05$.

The analysis of low caloric food – animal word pairs showed a somewhat different pattern. While there was still a significant main effect of group, $F(1, 114) = 5.74$, $p < .05$, partial $\eta^2 = .05$, and no main effect of probe position, $F(1, 114) = .01$, $p > .05$, there was also no significant group × probe position interaction, $F(1, 114) = .55$, $p > .05$. Thus, the overall attentional bias for food in the obese was driven primarily by an attentional bias for high rather than low caloric food.

Discussion

The obese participants showed an attentional bias for food. This finding is consistent with previous reports of biased attentional processing of food stimuli in obese individuals (Braet & Crombez, 2003; Castellanos et al., 2009; Graham et al., 2011; Nijs et al., 2010a,b; Long et al., 1994; Wertheim et al., 2011). In contrast, the normal weight controls did not show a food-relevant attentional bias. Some studies have nevertheless shown such a bias, albeit smaller than for obese individuals, in individuals of normal weight (Castellanos et al., 2009; Graham et al., 2011; Nijs et al., 2010a,b; Long et al., 1994; Phelan et al., 2011; Wertheim et al., 2011). A possible explanation for this discrepancy could be a difference in choice of non-food control stimuli. Unlike some previous studies, which paired food stimuli with office supplies, musical instruments or tools, we deliberately selected our control stimuli from a semantic category (i.e., animals) that is overall also appealing. Additionally, the words of each pair were individually matched on a range of indicators, including valence and arousal. Thus, perhaps not surprisingly, our normal weight controls did not preferentially direct their attention to food (e.g., pizza) over non-food (e.g., puppy) words.

Subsequent analyses indicated that the obese participants showed a bias primarily for high caloric food. Interestingly, the obese participants responded more slowly to probes overall. This general response slowing on attentional bias measures has previously been shown in other samples of obese adults (Nijs et al., 2010b) and children (Braet & Crombez, 2003).

Experiment 2

Experiment 1 demonstrated an attentional bias for food cues in the form of words in obese individuals. Using words as stimuli enabled us to exert control over our stimulus materials by individually matching the items of each pair for word length (number of letters and syllables). However, to increase ecological validity, Experiment 2 sought to replicate this finding using pictures as stimuli, thereby exposing participants to food cues in a manner more akin to the daily experiences of real life, as experienced in advertising. The main focus of this experiment, however, was to investigate whether the bias in attentional processing of food cues in obese individuals can be modified. To this end, we used a modified dot probe task to train obese participants to direct their attention toward (attend group), or away from (avoid group), food pictures. We predicted that attentional re-training would increase the food-related attentional bias in the attend group, and reduce this bias in the avoid group.

We also investigated whether the effect of the training manipulation generalised to an independent measure of biased information processing. There is mixed evidence from cognitive bias modification studies on alcohol as to whether the induced training effects generalise to other implicit bias measures (Field et al., 2007; Schoenmakers et al., 2007; Wiers, Rinck, Kordts, Houben & Strack, 2010; Wiers, Eberl, Rinck, Becker & Lindenmeyer, 2011). To achieve this here, participants were given a word stem completion task following the dot probe protocol. The word stem completion task presented participants with word stems that could be completed either as a food or an animal word. We predicted that participants in the avoid group would produce disproportionately fewer food than animal words on the word stem completion task than those in the attend group.

Finally, we also measured participants' awareness of the experimental contingencies during attentional re-training to examine its potential role on training effects. Findings from previous attentional bias modification studies on alcohol and cigarettes have been mixed. While some have found that training effects were restricted to participants who were aware of the experimental contingencies (Attwood, O'Sullivan, Leonards, Mackinstosh & Munafo, 2008; Field et al., 2007), others found that contingency awareness did not influence training effects (Field & Eastwood, 2005; Field, Duka, Tyler & Schoenmakers, 2009).

Method

Participants. Participants were 96 healthy obese (all BMIs ≥ 30 kg/m^2) community-dwelling women, aged 24 to 67 years (*M* = 48.88, *SD* = 10.42), who spoke English as their first language. They were recruited from the Adelaide metropolitan area via an advertisement in the local newspaper, and received a $30 honorarium. Mean BMI for the sample was 36.63 kg/m^2 (*SD* = 5.97). None had taken part in Experiment 1. As in Experiment 1, participants ate something two hours prior to testing. Hunger ratings were again relatively low (*M* = 19.80, *SD* = 21.58). Additionally, all participants reported that they ate and liked most foods, and were not vegetarian.

Design. The experiment used a 2 (training condition: attend, avoid) × 2 (time: pre-test, post-test) between-within subjects design. Participants were randomly assigned to the training conditions, subject to equal numbers per condition.

Materials.

Modified dot probe task. The stimuli were 80 digital coloured photographs comprising 20 food and 60 animal pictures. In line with Experiment 1, the food pictures depicted 10 high caloric (e.g., chips, ice cream) and 10 low caloric (e.g., pineapple, soup) food items. Likewise, the animal pictures featured generally well-liked species that are not commonly consumed in Western cultures (e.g., giraffe, koala). All pictures were scaled to 120 mm in width, whilst maintaining the pictures' original aspect ratio. Again two categories of stimulus pairs were constructed: critical (food – animal) and control (animal – animal), with 20 picture pairs per category. Within each pair, pictures were matched as closely as possible for perceptual characteristics (brightness, complexity), as well as 9-point scale ratings of valence, arousal and category representativeness. These were obtained from a pilot study in which 21 women aged 17 to 45 years (*M* = 23.67, *SD* = 8.28) rated 590 food and animal pictures. Another 14 picture pairs, unrelated to food or animals (e.g., car – beach ball), were created for practice and buffer trials.

Following standard attentional bias modification protocols (MacLeod et al., 2002), the modified dot probe procedure consisted of three phases: (1) a pre-training baseline assessment of participants' attentional bias for food (pre-test), (2) a training phase in which half the participants were trained to attend to food, and the other half were trained to avoid food (i.e., attend to animals), and (3) a post-training assessment of participants' attentional bias for food similar to the pre-test (post-test).

Pre-test. At pre-test, participants completed a standard dot probe task. On each trial, a fixation cross was displayed in the centre of the screen for 500 ms, followed by the presentation of a picture pair for 500 ms. The pictures were displayed on either side of the central position, with a distance of 40 mm between their inner edges. A dot probe was then displayed in the location of one of the previously presented pictures. Participants were asked to indicate as quickly as possible whether the dot probe appeared in the location previously occupied by the left or the right picture, by pressing the corresponding keys labelled L (‘z’) and R (‘/’) on the computer keyboard. The dot probe remained displayed until a response was made. The inter-trial interval was 500 ms.

The task commenced with 12 practice trials, followed by 2 buffer trials and 160 experimental trials. In the experimental trials, each of the 20 critical (food – animal) picture pairs and each of the 20 control (animal – animal) picture pairs was presented four times, once for each of the picture location (left or right) × dot probe location (left or right) combinations. Thus probes replaced each of the pictures in each pair with equal frequency (50/50). Trials were presented in a new randomly chosen order for each participant.

Training. In the attentional re-training phase, participants completed a modified dot probe task. Only the 20 critical (food – animal) picture pairs were used. These were each presented 16 times, for a total of 320 trials, with each picture presented 8 times on each side of the screen. Attentional bias was manipulated by varying the location of the dot probes for the two training conditions. Specifically, for participants in the attend condition, dot probes replaced food pictures on 90% of trials and animal pictures on 10% of trials, designed to direct attention toward food cues. For participants in the avoid condition, these contingencies were reversed, that is dot probes replaced food pictures on 10% of trials and animal pictures on 90% of trials, designed to direct attention away from food cues. A 90-10 distribution was used, as opposed to a 100-0 one, to reduce the obviousness of the contingency (Schoenmakers et al., 2007).

Post-test. The post-test was similar to the pre-test, except that there were no practice trials.

Word stem completion task. The word stem completion task was adapted from Kemps, Tiggemann and Hollitt (under revision). It consists of 23 three-letter word stems, which can be completed to form an unambiguous food word, animal word, and at least one reasonably high frequency alternative. For example, the word stem BEA__ could be completed as *beans* (food), *bear* (animal) or *beat* (neither food nor animal). Table 1 shows examples of possible (food and animal) words generated for these stems. An additional 10 control stems that cannot be completed as a food or animal word (e.g., EXC__, ACC__) were included to minimise the likelihood of participants becoming consciously aware of the food and animal themes in the word stems, and consequently trying to actively search for, or conversely, inhibit those words. The control stems were randomly interspersed among the target word stems. The entire 33-item word stem completion task is presented in Appendix A.

As shown in the Appendix, participants were instructed to complete the word stems with whatever word came to mind first. They were given two example stems, neither of which could be completed as a food or animal word, followed by the 33 stems to be completed. Performance on the task was scored by categorising each completion as a food, animal or other (i.e., neither food nor animal) word, and then summing the number of food and animal words generated. To adequately reflect the number of food words generated relative to the number of animal words generated, the number of food words was expressed as a proportion of the total number of food and animal words. Thus scores ranged from 0 (no food words) to .5 (an equal number of food and animal words) to 1 (no animal words).

Awareness of experimental contingencies. Following Field and Eastwood (2005), awareness of experimental contingencies was first assessed by an open-ended recall question and then by a multiple-choice recognition question. The open-ended question asked participants to describe the relationship between the type of pictures and the location of the probes during the training phase. The multiple-choice question asked participants to choose the correct statement from five different statements that described relationships between picture type and the probe location (e.g., “dots mainly appeared on the same side of the screen as food pictures”).

Procedure. Participants were tested individually in a quiet room in the Applied Cognitive Psychology Laboratory at Flinders University in a single session of 45 min. duration. Participants were seated approximately 50 cm in front of an IBM compatible computer with a 22-inch monitor. After giving informed consent, participants completed a brief demographics questionnaire, followed by the modified dot probe task. They then completed the contingency awareness measures and the word stem completion task. Finally, participants' height and weight were measured.

Results

Attentional bias. To investigate whether participants showed an attentional bias for pictorial food cues, we compared response times to dot probes replacing food and animal pictures of the critical trials (food – animal pairs) at pre-test. Response times of incorrect trials were discarded. Additionally, response times of less than 150 ms or more than 1500 ms were excluded as outliers, as were response times more than 3 *SD*s above or below the individual mean. Errors and outliers accounted for 1.04% and 0.6% of the data, respectively.

A paired samples *t* test showed that participants were faster to respond to probes replacing food pictures ($M = 458$ ms) than to probes replacing animal pictures ($M = 469$ ms), $t(95) = 4.54$, $p < .001$, $d = .14$, thus replicating the attentional bias for food in obese individuals with pictorial stimuli. Separate analyses for high and low calorie food showed the same pattern (high caloric food, $t(95) = 3.82$, $p < .001$, $d = .17$; low caloric food, $t(95) = 3.45$, $p < .01$, $d = .13$). Although the attentional bias for low caloric food was somewhat smaller, it was statistically significant.

Attentional bias modification. To assess the effect of the attentional training, we compared response times on critical trials at post-test with those at pre-test. For each test phase, an attentional bias score was calculated by subtracting the mean response times to probes that replaced food pictures from the mean response times to probes that replaced animal pictures, such that a positive score indicates an attentional bias for food.

These attentional bias scores were analysed by a 2 (training condition: attend, avoid) × 2 (time: pre-test, post-test) mixed model ANOVA. There was a significant main effect of training condition, $F(1, 94) = 19.86$, $p < .001$, partial $\eta^2 = .17$, with the attend group ($M = 21.82$) showing a greater attentional bias for food than the avoid group ($M = 5.00$). There was no main effect of time, $F(1, 94) = 1.41$, $p > .05$. Importantly, as can be seen in Figure 3, the predicted training condition × time interaction was significant, $F(1, 94) = 19.89$, $p < .001$, partial $\eta^2 = .18$. Paired samples *t* tests showed a significant increase in attentional bias scores from pre- to post-test in the attend group, $t(47) = 4.63$, $p < .001$, $d = .85$, and a significant decrease in the avoid group, $t(47) = 2.07$, $p < .05$, $d = .45$.

Separate analyses for high and low caloric food showed the same pattern. For both high and low caloric food, there was a significant main effect of training condition (high caloric food: $F(1, 94) = 20.81$, $p < .001$, partial $\eta^2 = .18$; low caloric food: $F(1, 94) = 7.64$, $p < .01$, partial $\eta^2 = .08$), no main effect of time (high caloric food: $F(1, 94) = .00$, $p > .05$; low caloric food: $F(1, 94) = 3.59$, $p = .06$), and a significant interaction between training condition and time (high caloric food: $F(1, 94) = 12.99$, $p < .001$, partial $\eta^2 = .12$; low caloric food: $F(1, 94) = 11.90$, $p < .001$, partial $\eta^2 = .11$). As shown in the top panel of Figure 4, attentional bias scores for high caloric food increased significantly from pre- to post-test in the attend group, $t(47) = 3.13$, $p < .01$, $d = .53$, and decreased significantly in the avoid group, $t(47) = 2.21$, $p < .05$, $d = .49$. The bottom panel of Figure 4 similarly shows a significant increase in attentional bias scores for low caloric food from pre- to post-test in the attend group, $t(47) = 4.22$, $p < .001$, $d = .85$. Although bias scores decreased from pre- to post-test in the avoid group, this change was not statistically significant, $t(47) = 1.00$, $p > .05$.

Word stem completion task. To investigate whether the effects of attentional training generalised to an independent measure of biased attentional processing, an independent samples *t* test was conducted comparing the proportion of food words generated on the word stem completion task between the attend and avoid groups. Although both groups produced a greater proportion of food than animal words (>.5) on this task, as predicted, participants in the avoid group produced a significantly greater proportion of animal words (food: *M* = .57; animal: *M* = .43) relative to those in the attend group (food: *M* = .68: animal: *M* = .32), *t*(94) = 2.37 = *p* < .05, *d* = .50.

Awareness of experimental contingencies. Approximately half the participants (N = 51; 53%) correctly recalled or recognised the relationship between the type of pictures and the location of the probes during the training phase; the other half (N = 45; 47%) were not aware of (or at least did not report) the experimental contingencies. To examine the effect of contingency awareness on attentional bias scores and word stem performance, the previous analyses were repeated with awareness (aware, unaware) as an additional between-subjects factor. Across analyses, there was no main effect of awareness, nor, most importantly, any interactions involving awareness (all *p*s > .05).

Discussion

Experiment 2 replicated the attentional bias for food in obese individuals using pictorial stimuli. More importantly, the experiment showed that this bias can be modified. As predicted, participants demonstrated changed biases for food pictures in accordance with their training condition, such that the attend group showed an increase in attentional bias following attentional re-training, whereas the avoid group showed a decrease. These findings are consistent with reports of attentional bias modification for emotionally threatening stimuli (Hertel & Mathews, 2011) and for addictive substances (Wiers et al., 2013).

Subsequent analyses indicated that attentional re-training altered attentional bias in the expected directions for both high and low caloric foods.

Importantly, the observed attentional re-training effects extended to an independent measure of biased information processing. In line with predictions, participants in the avoid group produced relatively fewer food than animal words on the word stem completion task than those in the attend group, indicative of reduced food and eating-related cognitions. Nevertheless, in absolute terms the avoid group still produced more food than animal words; however, this difference was substantially smaller than in the attend group. This suggests that the pre-existing bias for food in obese individuals, also shown in Experiment 1, cannot be eliminated altogether, but can be shifted toward another category, in this case animals. Additional re-training beyond the single session administered here may be necessary to alter this bias further, as Wiers et al. (2011) found generalised effects of alcohol-related bias modification only following multiple training sessions.

Finally, the training effects on attentional bias and word stem completions were observed across the board, regardless of whether participants were or were not aware of the experimental contingencies. This suggests that participants need not be consciously aware of the re-training to show its intended effects, consistent with findings from previous attentional bias modification studies on alcohol (Field & Eastwood, 2005; Field, Duka, Tyler & Schoenmakers, 2009).

General Discussion

The present experiments investigated biased attentional processing of food cues in obese individuals. Experiment 1 showed an attentional bias for food cues in obese women using words as stimuli. Experiment 2 replicated this finding using pictorial stimuli. In particular, both experiments showed an attentional bias for high caloric food. This may reflect a preference for high caloric food among obese individuals (Drewnowski, Kurth, Holden-Wiltse & Saari, 1992). Such biased attentional processing of high caloric food may make obese individuals particularly vulnerable to food advertising, as the majority of food commercials promote products high in fat, sugar and/or salt (Chapman, Nicholas & Supramaniam, 2006; Powell, Szczypka, Frank & Chaloupka, 2007), and also to other environmental food cues (e.g., bakeries, fast food outlets and confectionary aisles in supermarkets).

Theoretically, the observed attentional bias for food cues in obese individuals fits with contemporary explanations of enhanced responsivity to food-related stimuli in obesity. In particular, within cognitive-behavioural theories (Cox & Klinger, 2004; Williamson et al., 2004), this food-related bias reflects the activation of dysfunctional food schemas, which manifest as a preoccupation with food and eating. According to incentive sensitisation theory (Berridge, Ho, Jocelyn & DiFeliceantonio, 2010; Volkow & Wise, 2005), biased attentional processing of food cues in obesity is indicative of a heightened food reinforcement (i.e., a stronger motivation to eat), because of an aberrant brain reward system.

Experiment 2 further demonstrated that the food-related attentional bias in obese individuals can be modified. This mirrors the attentional re-training effects for addictive substances, such as alcohol and tobacco, previously shown in heavy drinkers and smokers (Attwood et al., 2008; Field & Eastwood, 2005; Field et al., 2007, 2009; Schoenmakers et al., 2007, 2010).While the observed increase in attentional bias for food cues is theoretically interesting, the fact that this bias can be reduced is most relevant from a practical perspective. Of particular significance is the finding that attentional re-training can reduce biased processing of high caloric food cues in the obese, as these have the potential to be most problematic in our “obesogenic” environment (Novak & Brownell, 2011). The findings also support the theoretical mechanism by which attentional re-training is argued to change biased processing of food stimuli, particularly by giving obese participants systematic practice in diverting attention away from rewarding, but potentially problematic, food cues, and orienting attention instead towards neutral (i.e., animals) cues. Participants need not be aware of the training manipulation to show the resultant changes in attentional bias. In fact, about half the participants reported not noticing the relationship between the location of the probe and the content of the pictures.

Importantly, the observed changes in attentional bias extended beyond participants' responses to dot probes at post-test to novel word stem completions. Thus the effects of attentional re-training are not specific to the particular training protocol but do generalise to other (limited) contexts. Such generalisation is important if attentional bias modification is to have any real-world application. Obese individuals need to be able to withstand unwanted food cues in all different situations, not just the particular ones learned during training.

Attentional bias modification does not target the maladaptive behaviour itself, but rather the automatic attentional processes that are thought to underpin it. This makes it a particularly suitable intervention for obese individuals for whom biased attention toward food cues is a contributing factor to unwanted overeating. Attentional bias modification trains people to suppress the automatic tendency to attend to maladaptive stimulus cues. In so doing, it is thought to give them more time for decision making and thus refrain from reacting to such cues outside of conscious control (Wiers et al., 2013).

The finding that attentional re-training can reduce biased processing of food cues in obese individuals thus offers potential scope for curbing pathological (over)eating. Attentional bias modification is based on the premise that if biased attention maintains dysfunctional behaviour, interventions that reduce the attentional bias should in turn reduce the behaviour. In support, addiction research has shown that changes in attentional bias are indeed linked to changes in consumption. For example, Field and Eastwood (2005) showed that participants trained to direct their attention away from alcohol cues drank less beer in a subsequent taste test. It remains to be determined whether attentional bias modification could similarly lead to reduced food intake in obese individuals. Such evidence of attentional re-training effects on food intake would further elucidate the direction of the relationship between attentional bias for food and overeating. At present it is unclear whether attentional bias for food leads to overeating, or whether conversely individuals who overeat develop an attentional bias for food (Wertheim et al., 2011).

To the extent that experimental manipulation of attentional bias for food cues can indeed reduce actual food intake in obese people, targeting the attentional processes that underlie the heightened responsiveness to environmental food cues in obese individuals could potentially improve the effectiveness of weight-loss programs. Attrition rates of 10-80% have been reported across various behavioural, pharmacological and surgical weight loss treatments (Inelmen et al., 2005). In addition, about half the weight lost is often regained within 1 year and almost all is typically regained within 3-5 years post-treatment (Jeffery et al., 2000). One reason that obese individuals may have difficulty losing weight is that they are surrounded by environments containing food cues that automatically capture attention. If this biased processing of food cues continues to occur even after weight is lost, weight maintenance will prove very difficult. Addressing food-related attentional biases as part of a multi-pronged intervention strategy could help improve the success of weight-loss treatments, and contribute to the general goal of reducing obesity.

A number of limitations of the present study need to be acknowledged. First, the experiments were conducted in a laboratory setting. Future research will need to determine whether effects of attentional re-training to food cues can also be obtained outside the laboratory. For example, home-based delivery of attentional bias modification via the internet has already been trialled in the field of anxiety (Eldar et al., 2012; See, MacLeod & Bridle, 2009). Second, the effects of attentional re-training on biased processing and word stem completions were assessed immediately after training. Future research will need to address the longevity of the observed attentional re-training effects. If attentional bias modification of food cues is to have practical application, it is important that its positive effects are maintained over time. Emerging evidence from addiction research points to the stability of attentional bias modification effects, at least over the short term. For example, Schoenmakers et al. (2010) reported sustained reductions in attentional bias for alcohol-related stimuli in alcohol-dependent patients three days after training. Third, while it might be argued that the effect of attentional re-training is due to priming rather than the development of attentional re-direction, the protocol of presenting the food and animal pictures simultaneously makes this unlikely, as participants are exposed to both stimulus categories equally. It is the experimental manipulation of the probe position then that specifically draws the participant's attention either towards or away from the location of the food (or animal) cue. Finally, future studies need to test whether attentional re-training effects extend to eating measures within the same study.

In conclusion, the present study adds to a growing body of research on attentional bias for food cues in obesity. We have shown that the food-related bias observed in obese individuals can be modified. In so doing, we have extended the attentional bias modification paradigm from anxiety and addiction to obesity. Future research could seek to further extend the paradigm to individuals with other problem eating behaviours, such as those who suffer from anorexia or bulimia nervosa, and who similarly show an attentional bias for food (for a review, see Brooks, Prince, Stahl, Campbell & Treasure, 2011). More generally, attentional re-training could be applied to other problem health behaviours, such as insomnia, in which attentional biases also play a role. The current results present an encouraging first step in tackling biased attention to environmental food cues in the obese. They further suggest that attentional bias modification could potentially be used to combat pathological (over)eating and improve the success of weight-loss treatments.

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Table 1

Examples of possible food and animal word completions for the 22 word stems

Word stem	Food word	Animal word
BEA	Beans	Bear
FER	Ferrero	Ferret
ROA	Roast	Roach
DON	Donut	Donkey
ORA	Orange	Orang-utan
BUR	Burger	Burmese
CAN	Candy	Canine
GRA	Grapes	Grasshopper
TUR	Turnip	Turtle
DOL	Dolmades	Dolphin
TOR	Tortilla	Tortoise
DIN	Dinner	Dingo
MAY	Mayonnaise	May-fly
PAN	Pancake	Panda
COC	Coconut	Cockatoo
WAL	Walnut	Walrus
PAR	Parsnip	Parrot
CHE	Cheese	Cheetah
POR	Porridge	Porcupine
PEN	Penne	Penguin
SNA	Snack	Snake
TOA	Toast	Toad
LEM	Lemon	Lemur

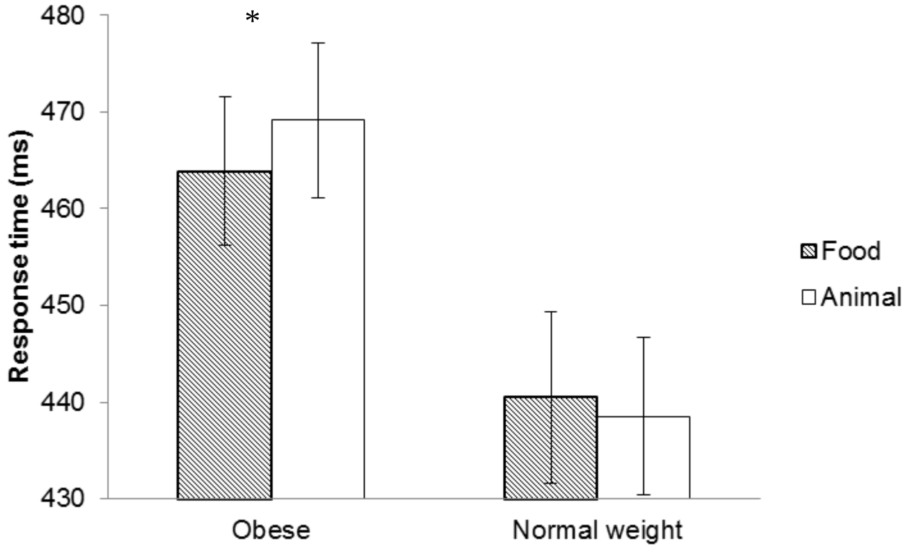

Figure 1. Mean response times (with standard errors) to probes replacing food and animal stimuli for obese and normal weight individuals in Experiment 1; * *p* < .05.

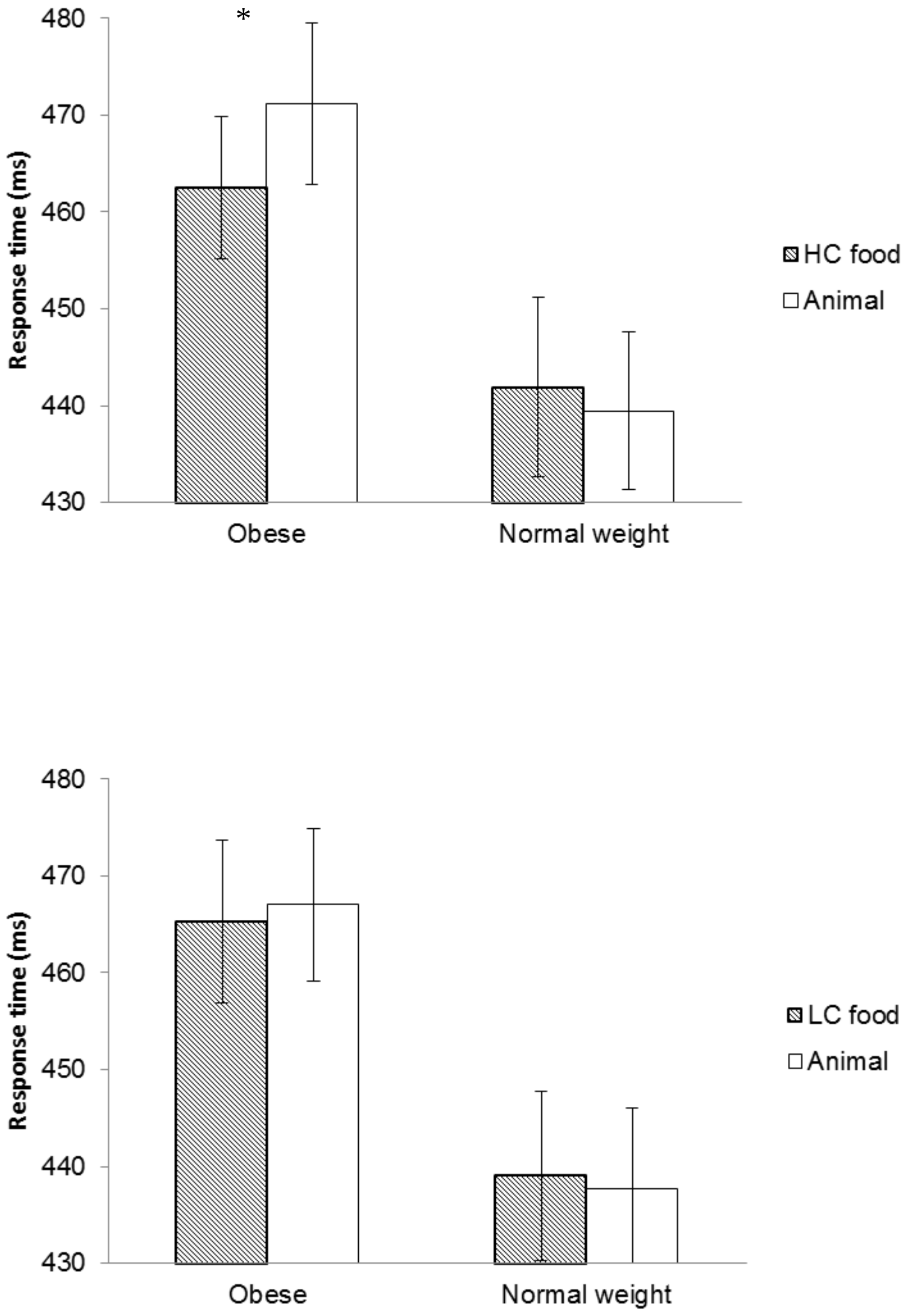

Figure 2. Mean response times (with standard errors) to probes replacing food and animal stimuli for obese and normal weight individuals in Experiment 1; high caloric (HC) food stimuli (top panel) and low caloric (LC) food stimuli (bottom panel); * $p < .05$.

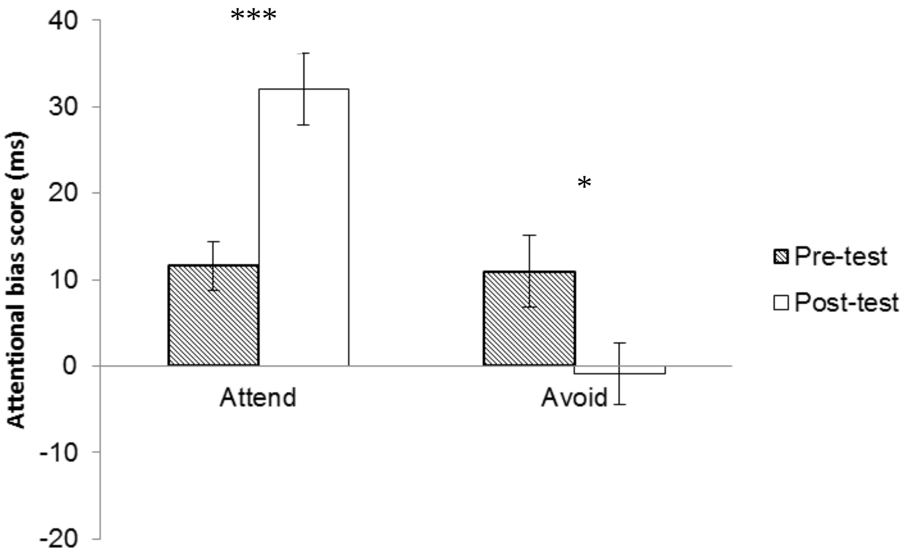

Figure 3. Mean attentional bias scores (with standard errors) for the attend and avoid conditions at pre- and post-test in Experiment 2; * *p* < .05, *** *p* < .001.

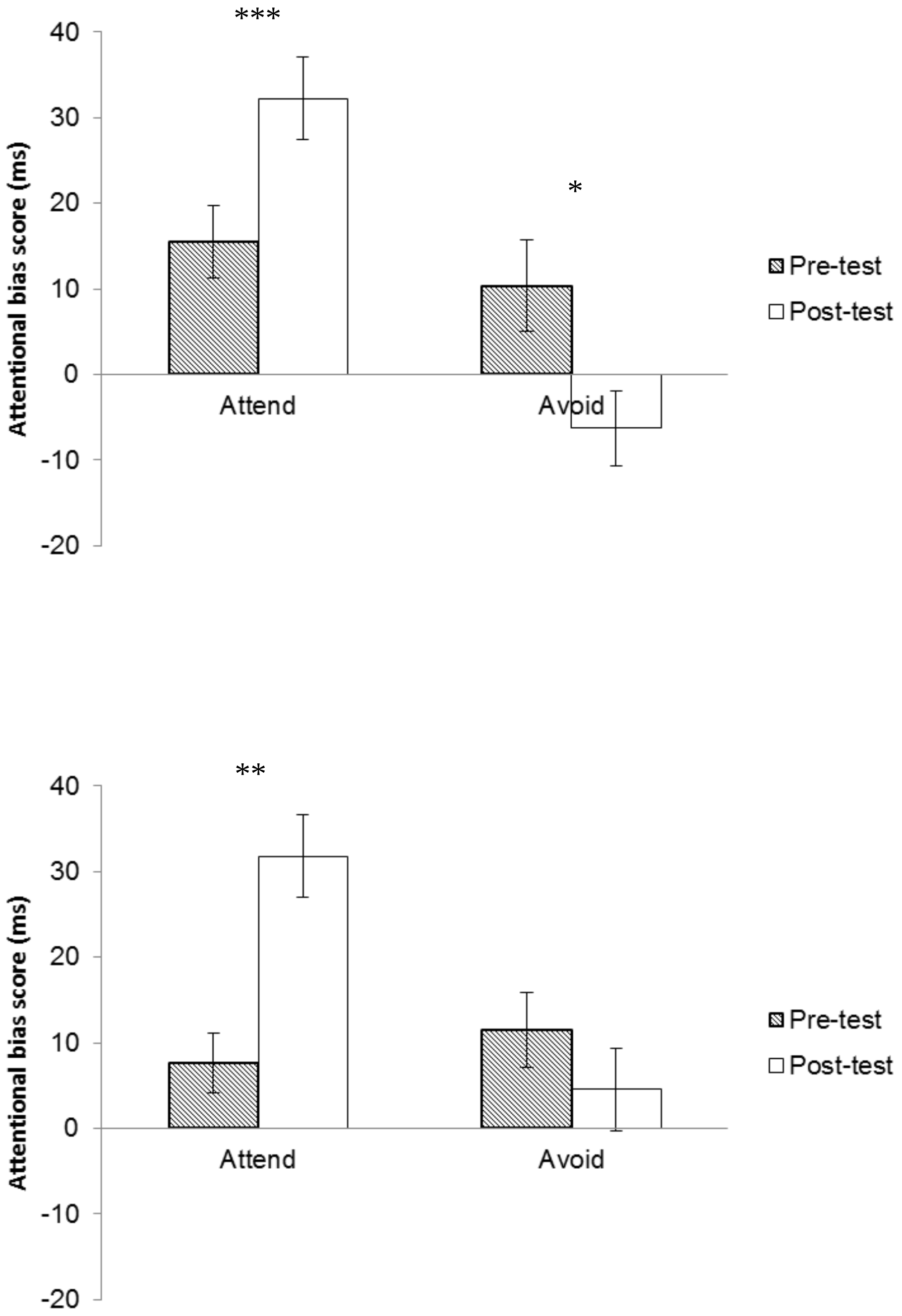

Figure 4. Mean attentional bias scores (with standard errors) for the attend and avoid conditions at pre- and post-test in Experiment 2; high caloric food stimuli (top panel) and low caloric food stimuli (bottom panel); * *p* < .05, ** *p* < .01, *** *p* < .001.

Appendix A

Word stem completion task

Please complete the following word stems in order with whatever word comes to your mind first. The completed words must be real English words, and **must not** be proper nouns (i.e. names).

For example;

EXA ______ → EXA mple__ or EXA mination or EXA ………
FRE ______ → FRE eze___ or FRE e______ or FRE ………

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1. BEA_________
2. FER_________
3. LAN ________
4. ROA ________
5. DON________
6. ORA________
7. SOC_________
8. BUR ________
9. CAN________
10. FAC_________
11. GRA________
12. TUR_________
13. DIF_________
14. DOL________
15. TOR_________
16. REA_________
17. DIN_________
18. MAY________
19. PAN________
20. SYM________
21. COC________
22. THR_________
23. WAL________
24. PAR_________
25. TRA_________
26. CHE_________
27. POR_________
28. ACC________
29. PEN_________
30. SNA ________
31. EXC_________
32. TOA________
33. LEM________