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Combined Effects of Cognitive Bias for Food Cues and Poor Inhibitory Control on Unhealthy Food Intake

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Abstract

The present study aimed to investigate the combined effects of cognitive bias (attentional and approach biases) and inhibitory control on unhealthy snack food intake. Cognitive biases reflect automatic processing, while inhibitory control is an important component of controlled processing. Participants were 146 undergraduate women who completed a dot probe task to assess attentional bias and an approach-avoidance task to asses approach bias. Inhibitory control was measured with a food-specific go/no-go task. Unhealthy snack food intake was measured using a so-called "taste test". There was a significant interaction between approach bias and inhibitory control on unhealthy snack food intake. Specifically, participants who showed a strong approach bias combined with low inhibitory control consumed the most snack food. Theoretically, the results support contemporary dual-process models which propose that behaviour is guided by both automatic and controlled processing systems. At a practical level, the results offer potential scope for an intervention that combines re-training of both automatic and controlled processing.

Combined Effects of Cognitive Bias for Food Cues and Poor Inhibitory Control on Unhealthy Food Intake

During the last three decades, the global prevalence of overweight and obesity has doubled, with 35% of adults classified as overweight and 11% as obese (WHO, 2013). One important contributor to chronic health problems such as overweight and obesity is unhealthy eating (NHMRC, 2003). The contemporary Western diet is characterised by unhealthy eating, in particular consuming too much fat, salt and sugar. Given the potential negative health consequences of unhealthy eating, it is important to investigate the cognitive mechanisms that underlie such behaviour. Specifically, recent theoretical perspectives and empirical evidence suggest that automatic and controlled cognitive processing make important contributions to unhealthy behaviour.

Dual-process models (e.g., Strack & Deutsch, 2004) propose that our behaviour is determined by two different information processing systems, i.e., automatic and controlled processing. Automatic processing is fast, implicit and effortless, and includes affective (i.e., attitudes, preferences) and motivational (i.e., attending to, approaching) responses to relevant stimuli, such as unhealthy food cues. In contrast, controlled processing is effortful, slow, and explicit, and involves conscious decisions based on personal goals and standards (e.g., health and weight loss). These two processing systems elicit conflicting signals, and the outcome is determined by the relative strength of each processing system. According to dual-process models, behaviour is guided by automatic processing and regulated by controlled processing (if cognitive resources are available). For example, the presence of unhealthy food cues may elicit a conflict between the two systems, i.e., automatically attending to and approaching such cues while maintaining incompatible goals related to health and weight. Thus, a strong automatic system (an attentional or approach bias for food cues) and a weak controlled system (poor inhibitory control or working memory capacity) may result in unhealthy eating.

Automatic and controlled processing systems have given rise to two separate lines of research. Support for the role of automatic processing in eating behaviour generally comes from research investigating cognitive biases for food cues. A cognitive bias refers to "systematic selectivity in information processing that operates to favour one type of information over another" (MacLeod & Matthews, 2012, p. 191). Most research has focused on attentional bias, which refers to the automatic allocation of attention to food cues in preference to other cues (MacLeod & Matthews, 2012). More recently, researchers have turned their focus toward approach bias, which is the automatic behavioural tendency to move toward rather than avoid food cues (Wiers et al., 2013a). Studies have demonstrated biased attentional processing of high-caloric food cues in relation to neutral (non-food) cues in healthy weight participants (Nijs, Franken, & Muris, 2010; Werthmann et al., 2013). Both attentional and approach biases for food cues have also been documented in populations with eating-related issues. Specifically, restrained (Hollitt, Kemps, Tiggemann, Smeets, & Mills, 2010; Veenstra & de Jong, 2010) and external eaters (Brignell, Griffiths, Bradley, & Mogg, 2009; Hou et al., 2011; Nijs, Franken, & Muris, 2009), as well as overweight and obese individuals (Castellanos et al., 2009; Havermans, Giesen, Houben, & Jansen, 2011; Nijs et al., 2010a; Nijs, Muris, Euser, & Franken, 2010b), are faster to detect and approach high-caloric food cues relative to neutral cues.

Furthermore, research has demonstrated a positive correlation between attentional biases for unhealthy food cues (e.g., cake, salted peanuts) and the subsequent consumption of snack foods during a laboratory taste test in both healthy weight and obese participants (Nijs, Muris, Euser, & Franken, 2010; Werthmann et al., 2011). Research from our laboratory (Kakoschke, Kemps, & Tiggemann, 2014; Kemps, Tiggemann, Martin, & Elliot, 2013; Kemps, Tiggemann, Orr, & Grear, 2014), as well as others (Werthmann, Field, Roefs, Nederkoorn, & Jansen, 2013), has also found that experimentally reducing an attentional bias for unhealthy food cues decreases unhealthy food intake. This evidence is consistent with the idea that cognitive biases for food cues play a causal role in consumption (Berridge, 2009). Similar findings have also been shown for alcohol (Field & Eastwood, 2005) and cigarettes (Attwood, O'Sullivan, Leonards, Mackintosh, & Munafo, 2008). Nevertheless, the evidence is mixed as some studies have found no such link between attentional bias and consumption of food (Hardman, Rogers, Etchells, Houstoun, & Munafo, 2013), alcohol (Field et al., 2007; Fadardi & Cox, 2009), and cigarettes (Field, Duka, Tyler, & Schoenmakers, 2009). In contrast, the smaller amount of research on approach bias shows a more consistent link between approach bias and consumption of alcohol (Wiers et al., 2009; Wiers, Rinck, Kordts, Houben, & Strack 2010) and cannabis (Cousijn et al., 2011). One possible explanation for these contradictory findings is that attentional and approach biases behave differently, as has been evidenced by research in the alcohol domain. Specifically, Sharbanee, Stritzke, Wiers, and MacLeod (2013) demonstrated that these two cognitive biases are distinct mechanisms that can make independent contributions to consumption. Another potential explanation for the overall mixed evidence is that the previous research has not taken into account the role of controlled processing in consumption.

Research investigating the role of controlled processing in eating behaviour has primarily focused on inhibitory control (or response inhibition), which has been defined as “the ability to inhibit a behavioural impulse in order to attain higher-order goals, such as weight loss” (Houben, Nederkoorn, & Jansen, 2012, p. 550). A recent study by Loeber et al. (2012) found that both healthy weight and obese participants were less effective at inhibiting behavioural responses to food cues relative to neutral (non-food) cues. Furthermore, studies have shown that obese participants were less effective at inhibiting responses to neutral cues (Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006) as well as to food-related cues (Nederkoorn, Smulders, Havermans, Roefs & Jansen, 2006) than healthy weight participants.

Several studies have also demonstrated that poor inhibitory control is associated with increased food intake during a laboratory taste test in both healthy weight (Guerrieri, Nederkoorn, & Jansen, 2007) and overweight or obese women (Appelhans et al., 2011). In addition, poor inhibitory control predicted an increase in weight (BMI) over a one year period in a sample of healthy weight women (Nederkoorn, Houben, Hofmann, Roefs & Jansen, 2010). Some studies have also shown that experimentally increasing inhibitory control reduces chocolate (Houben & Jansen, 2011) and alcohol (Houben, Nederkoorn, Wiers, & Jansen, 2011) consumption; however, Guerrieri et al. (2007b) found that experimentally increasing behavioural inhibition had no effect on milkshake consumption in a laboratory taste test. Furthermore, inhibitory control is related to working memory capacity, which is the ability to store and process goal-relevant information (Conway, Kane & Engle, 2003). A recent study found that experimentally increasing working memory capacity reduced alcohol intake in a sample of problem drinkers (Houben, Wiers, & Jansen, 2011).

As indicated above, prior research has largely focused on automatic or controlled processing separately. However, it may be their combination that is most important for consumption. In line with dual-process models, recent meta-analyses suggest that a cognitive bias for appetitive cues combined with poor inhibitory control may result in unhealthy behaviour, such as consuming appetitive substances like drugs and alcohol (Field & Cox, 2008; Coskunpinar & Cyders, 2013). Nederkoorn et al. (2010) investigated this theoretical prediction in the food domain and found that automatic and controlled processing interacted in determining an increase in BMI over a one year period in healthy weight women. Specifically, women with strong implicit preferences for food and low inhibitory control gained the most weight. Other studies have shown that the combination of strong implicit preferences and low inhibitory control predicts candy (Hofmann, Friese, & Roefs, 2009) and alcohol (Houben & Wiers, 2009) intake on a laboratory taste test. The above studies measured automatic processing with the implicit association task, which assesses evaluative attitudes for appetitive cues. However, we chose to focus on the motivational bias component of automatic processing. Similarly, in the alcohol domain, Peeters et al. (2012) recently found that the combination of an approach bias for alcohol and low inhibitory control (measured by the Stroop task) predicted alcohol use in adolescent drinkers. To the best of our knowledge, this finding has not been demonstrated in the food domain. In addition, the above studies have all measured inhibitory control in general, not specifically related to food. Yet specific food-related inhibitory control needs to be examined as a more proximal potential mechanism associated with unhealthy eating (Appelhans et al., 2011; Meule et al., 2014).

The aim of the current study was to investigate the combined effects of automatic and controlled processing on unhealthy food intake. Cognitive biases for food cues were assessed as an indicator of automatic processing, and food-specific inhibitory control was assessed as an important component of controlled processing. Both of the two main forms of cognitive bias, namely attentional bias and approach bias were included. Attentional bias was assessed by the often used dot probe task, developed by Macleod, Matthews and Tata (1986). Approach bias was assessed by the approach-avoidance task of Rinck and Becker (2007). Inhibitory control was assessed using the food-related go/no-go task of Houben and Jansen (2011). A so-called "taste test" was used to measure unhealthy food consumption. It was predicted that a stronger cognitive bias together with lower inhibitory control would lead to increased unhealthy food intake. This was tested for the two different components of cognitive bias (attentional and approach) separately.

Method

Participants.

Participants were 146 women recruited from the Flinders University undergraduate student population. They were aged 18-25 years (M = 20.20, SD = 2.64). Most participants were within the healthy weight range (i.e. 18.5-24.9 kg/m^2) with a mean BMI of 22.9 kg/m^2, (*SD* = 5.11). Only women were recruited as they have shown a greater tendency to overeat (Burton, Smit, & Lightowler, 2007). Participants were included if they spoke English as their first language, liked most foods, and did not have any food allergies or dietary requirements. As hunger has been linked to cognitive biases for food cues (Mogg, Bradley, Hyare, & Lee, 1998; Seibt, Hafner, & Deutsch, 2007) and poor inhibitory control (Nederkoorn, Guerrieri, Havermans, Roefs, & Jansen, 2009), 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. Participants also rated their current level of hunger on a 100 mm visual analogue scale ranging from “not hungry at all” to “extremely hungry” (Grand, 1968). Mean hunger ratings were around the mid-point of the scale ($M = 49.7$, $SD = 24$), and did not correlate with measures of cognitive biases, inhibitory control, or consumption ($.03 < r < .08$, *p*s > .05).

Materials.

Stimuli. The stimuli were 80 digital coloured photographs (presented in a resolution of approximately 1024 x 768 pixels) comprising 20 food and 60 animal pictures. The food pictures depicted food items high in sugar, salt and/or fat (e.g., chocolate, potato chips). Animals were chosen for the comparison category of neutral non-food stimuli as they, like food, are overall appealing. Animal pictures depicted well-liked species that are not commonly consumed in Western society (e.g., giraffe, koala.). For the dot probe task, the pictures were divided into 20 critical pairs (food-animal) and 20 control non-food pairs (animal-animal). Each picture pair was individually matched on characteristics such as quality, brightness, and size, as well as ratings of pleasure and arousal. These ratings were obtained from a previous pilot study, in which 21 women aged 17-45 years ($M = 23.67$, $SD =$

8.28) rated 590 food and animal pictures on 9-point pleasure and arousal scales (Kemps, Tiggemann, & Hollitt, 2014). The same stimulus set was used for all three computer tasks.

Dot probe task. Following the procedure of MacLeod et al. (1986), each trial began with the display of a fixation cross in the centre of the computer screen presented for 500 ms. This was followed by the presentation of a picture pair for 500 ms. The pictures were displayed on the left and right hand side of the screen and each were an equal distance from the centre. When the pictures disappeared, a small dot probe appeared in the location of one of the pictures and remained there until the participant responded. Participants were asked to press the corresponding key on the keyboard (the key labelled “L” for left or “R” for right) to indicate, as quickly as possible, whether the dot probe replaced the picture on the left or right hand side of the screen. Each picture pair was presented four times so that every combination of the replacement of the dot probe position (left or right picture location and left or right dot probe location) was presented, for a total of 160 trials.. The picture pairs were presented in a different random order for each participant and the dot probes replaced the pictures in each pair with equal frequency (50/50).

Participants’ reaction times (ms) were recorded on each trial. An attentional bias score was calculated for each participant by subtracting the reaction times to the dot probes replacing unhealthy food pictures from the reaction times to the dot probes replacing animal pictures. Therefore, positive scores indicate an attentional bias towards unhealthy food, while negative scores indicate an attentional bias away from unhealthy food.

Approach-Avoidance task. Following Rinck and Becker (2007), the approach-avoidance task was used to measure an approach-avoidance bias. This task, originally developed for anxiety disorders was adapted here for the food domain. The approach-avoidance task consisted of 160 trials. On each trial, participants began by pressing the start button on the top of a joystick. A picture of an unhealthy food or an animal then appeared in the centre of the screen. Participants were instructed to pull (approach) or push (avoid) the joystick according to whether the picture was presented in portrait or landscape format. These instructions were counterbalanced (i.e., half of the participants pulled for portrait and pushed for landscape and half vice versa). Pulling the joystick increased the picture size (as if physically approaching the picture), while pushing the joystick decreased the picture size (as if moving away from the picture). The picture disappeared once the participant had pulled or pushed the joystick. Participants were asked to respond as quickly and accurately as possible. Each picture was presented four times, twice in portrait format and twice in landscape format, and participants were asked to pull and push the food and animal pictures with equal frequency (50/50). The joystick was part of an apparatus that was connected to the table to prevent it from moving around during the task.

Participants' reactions times were recorded on each trial. For each participant, reaction time scores were calculated for pulling and pushing the food and animal pictures. The primary outcome measure was approach bias for food, which was calculated as the difference between median pushing and pulling reaction times for food pictures. Positive scores indicate an approach bias for food (i.e., tendency to pull faster than push an image), whereas negative scores indicate an avoidance bias for food (i.e., faster push than pull) (Wiers et al., 2013).

Go/no-go task. Following Houben and Jansen (2011), a food-related version of the go/no-go task was used to measure inhibitory control. The go/no-go task consisted of two blocks of 160 trials. On each trial, a picture was presented together with a go or a no-go cue (i.e., the letters 'p' or 'f') for 1500 ms. The go/no-go cues were displayed in black font type and were presented randomly in one of four locations near the outside corners of the pictures. Participants were instructed to press the space bar when a go cue was displayed on the picture, and to refrain from responding when a no-go cue was displayed. Instructions regarding letter type (‘p’ versus ‘f’) and response assignment (go versus no-go) were counterbalanced. The food and animal pictures were each presented eight times so that every combination of letter type (‘p’ or ‘f’) and letter location (left: top, bottom; right: top, bottom) was presented. Pictures were presented in a different random order for each participant, and food and animal pictures were paired with a go cue with equal frequency (50/50).

The number of commission errors (i.e., space bar pressed in response to a no-go cue) and the number of omission errors (i.e., space bar not pressed in response to a go cue) were recorded. Following previous studies (e.g., Bezdjian, Baker, Lozano, & Raine, 2009; Muele & Kubler, 2014), the primary outcome measure was the percentage of commission errors in response to food pictures, with a higher percentage of errors indicative of poorer inhibitory control.

Consumption. Consumption was measured using a so-called taste test. Participants were presented with a platter comprising four snacks (two sweet and two savoury): M&Ms, chocolate-chip biscuits, potato chips, and pretzels. The four foods were presented in equally-filled separate bowls and were chosen as they are commonly consumed and are bite-sized to facilitate eating. The presentation order of the bowls was counterbalanced across participants using a 4 × 4 Latin square. Participants were instructed to taste and rate each snack on several dimensions (e.g., flavour, likelihood of purchase). They were given 10 minutes to complete their ratings and told that they could try as much of the food as they liked. The amount of each food consumed was calculated by subtracting the weight (in grams) of the snacks after the taste test from the weight of the snacks before the taste test. The weight in grams for each food was then converted into the number of calories consumed and summed to obtain a total measure of intake.

Procedure

The experiment took place in the Food Laboratory in the School of Psychology at Flinders University, South Australia. The testing session took approximately one hour. After providing informed consent, participants completed a brief demographics questionnaire, followed by the three computer tasks presented in counterbalanced order, and finally the taste test. The study was approved by the University's Social and Behavioural Research Ethics Committee.

Results

Statistical considerations.

Data were examined to ensure assumptions underlying statistical analysis were met. Participants' response times for attentional bias and approach bias, as well as commission errors and consumption that were more than 3 *SD* from the mean were identified as outliers and were changed to plus or minus one unit from the first non-outlier (Tabachnick & Fidell, 1989). An alpha value of .05 was used to determine significant *p* values.

Descriptive statistics.

As expected, participants showed an attentional bias for food cues as indicated by a positive mean bias score, although the large standard deviation indicated that there was a considerable range in scores ($M = 8.26$, $SD = 24.59$). To formally test this, a 2 (target [food] location: left vs. right) x 2 (probe/response location: left vs. right) repeated measures ANOVA was conducted on the mean reaction times of the critical trials. The means, as presented in Table 1, showed no main effects of target location, $F(1, 145) = 1.95$, $p = .165$, or probe location, $F(1, 145) = .114$, $p = .736$. However, the interaction was significant, $F(1, 145) = 16.66$, $p < .001$. The results confirm that, irrespective of probe/response position, participants were faster to respond on compatible trials (when the probe replaced the target [food]) ($M = 373.46$, $SD = 51.61$), than on incompatible trials (when the probe replaced the non-target [animal]) ($M = 381.79$, $SD = 54.98$), which shows an attentional bias for food cues.

Table 2 presents the approach bias scores for both food and animal cues (although only the approach bias for food is of interest). As expected, participants showed an approach bias for food cues, as indicated by a positive mean bias score (*M* = 32.32, *SD* = 103.09). They also showed an approach bias for animal cues (*M* = 31.05, *SD* = 127.11). A 2 (picture type: food vs. animal) x 2 (joystick movement: push vs. pull) repeated measures ANOVA confirmed a significant main effect of joystick movement, $F(1, 145) = 12.132$, $p = .001$, whereby participants were faster to pull the joystick (‘approach’) than to push it. The main effect of picture type, $F(1, 145) = .024$, $p = .876$, and the interaction were not significant, $F(1, 145) = .045$, $p = .833$. This indicates that participants showed an approach bias for food (and animals).

For inhibitory control for food, participants produced a relatively low percentage of commission errors (*M* = 3.04, *SD* = 4.81), indicating on average good inhibitory control. Overall, there were very few omission errors (*M* = .015%, *SD* = .097), indicating good attention.

Effects of cognitive bias and inhibitory control for food on consumption.

A series of hierarchical multiple regression analyses was conducted to investigate the combined effects of cognitive bias and inhibitory control for food on consumption. This analysis was done separately for attentional bias and approach bias (see Figure 1 for graphical representations of the results).

For attentional bias, centred attentional bias scores and commission errors were entered in Step 1, and the product term representing the interaction between these two variables in Step 2. As can be seen in Figure 1a, the attentional bias results were in the predicted direction. However, they fell short of significance. The main effects of neither attentional bias, $R^2 = .007$, $F\ (1, 143) = 1.02$, $p = .315$, nor inhibitory control, $R^2 = .00$, $F\ (1, 144) = .00$, $p = .879$, explained a significant proportion of the variance in consumption. Nor did the product term explain any additional variance in consumption, R^2 Change = .016, *F Change* (1, 141) = 1.23, *p* = .269.

A similar analysis was conducted for approach bias. In this case, approach bias for food, approach bias for animals, and inhibitory control for food were entered in Step 1, and the two-way interaction terms with inhibitory control (approach bias for food x inhibitory control; approach bias for animals x inhibitory control) were entered in Step 2. Step 1 showed no significant main effects of approach bias for food, R^2 = .003, *F* (1, 144) = .50, *p* = .481, approach bias for animals, R^2 = .012, *F* (1, 144) = .02, *p* = .881, or inhibitory control for food, R^2 = .00, *F* (1, 144) = .00, *p* = .879. However, Step 2 showed that the product terms explained a significant additional 8.1% of the variance in food consumption, R^2 Change = .036, *F Change* (1, 142) = 3.597, *p* = .031. Specifically, the approach bias for food x inhibitory control interaction was significant (β = .355, *p* = .009), whereas the approach bias for animals x inhibitory control interaction was not (β = -.055, *p* = .567).

In order to determine the form of the significant interaction, simple slopes analyses were conducted. As shown in Figure 1b, inhibitory control for food had no effect on food consumption in women with a low approach bias, *B* = -1.63, *t*(145) = -1.02, *p* = .308. In contrast, for women with a high approach bias, those who made a higher percentage of commission errors (indicating lower inhibitory control) consumed significantly more food than those who made a lower percentage of commission errors (indicating higher inhibitory control), *B* = 6.417, *t*(145) = 2.04, *p* = .044. Thus, individuals who consumed the most unhealthy snack food showed a high approach bias for food cues and low inhibitory control (i.e., a high percentage of commission errors) in relation to food cues.

Discussion

The aim of this study was to investigate the combined effects of automatic and controlled processing on unhealthy food intake. Attentional and approach biases were assessed as an indicator of automatic processing, and inhibitory control was assessed as an indicator of controlled processing. Results indicated that neither type of cognitive bias nor inhibitory control alone predicted unhealthy food intake. However, approach bias for food interacted with inhibitory control to predict unhealthy food intake. Specifically, for women with a higher approach bias, those with lower inhibitory control consumed more food than those with higher inhibitory control. In contrast, for women with a lower approach bias, their level of inhibitory control did not predict the amount of food consumed. These findings suggest that consumption of unhealthy food is determined by a combination of automatic and controlled processing. Specifically, participants who showed a high approach bias for food combined with low inhibitory control consumed the most unhealthy snack food.

These findings extend to the food domain previous research which has shown that implicit preferences for alcohol cues (as measured by an IAT with word stimuli) interact with inhibitory control to predict increased alcohol intake (Houben & Wiers, 2009). Further, previous research has shown that tasks which use word stimuli, like the IAT, may be less effective than tasks using pictorial stimuli, like the approach-avoidance task used in the present study, in determining automatic processing of real-world food cues (Roefs, Werrij, Smulders & Jansen, 2006). The current study has also extended previous research on implicit preferences for food cues (Hofmann et al., 2009; Nederkoorn et al., 2010) to another component of automatic processing, namely motivational cognitive biases. In addition, food-specific inhibitory control was measured, rather than a general inability to inhibit responses (Houben & Wiers, 2009; Peeters et al., 2012). Food-specific inhibitory control has been argued to be particularly important with regard to achieving a more detailed understanding of the mechanisms which may be associated with unhealthy eating (Appelhans, et al., 2011; Meule, 2014). In support, neuroimaging research has shown that brain regions associated with motivation and disinhibition are activated in obese people in response to unhealthy food images (Carnell, Gibson, Benson, Ochner, & Geliebter, 2012).

The current findings are consistent with contemporary dual-process models (Strack & Deutsch, 2004) which propose that behaviour is determined by a combination of automatic and controlled processing. Specifically, the current study has demonstrated that motivational cognitive biases and inhibitory control interact to predict unhealthy eating behaviour. Appetitive food cues elicit automatic approach-action tendencies in some individuals. Individuals with a strong controlled system are able to inhibit responses to such cues. In contrast, those with a weaker controlled system are unable to inhibit this response, which leads to the consumption of unhealthy food. Thus, the present study provides empirical support for the theoretical predictions proposed by dual-process models, as well as recent meta-analyses (Field & Cox, 2008; Coskunpinar & Cyders, 2013).

Neither attentional nor approach bias alone made a significant contribution to food intake. The finding for attentional bias is not surprising as previous research has been inconsistent, and some studies have shown no link with consumption (Field et al., 2007; Fadardi & Cox, 2009; Field et al., 2009; Hardman et al., 2013). Questions have also been raised regarding the reliability of the dot probe task (Schmulke, 2005; Price et al., 2014). Approach bias for food also did not make an independent contribution to consumption, but interacted with inhibitory control for food in predicting unhealthy eating. One possible explanation is that a main effect of approach bias will be dependent on the sample. Specifically, the interaction showed relatively less effect of approach bias on consumption for participants with high inhibitory control. In contrast, approach bias did have the predicted effect on consumption for participants with low inhibitory control. Therefore, a main effect of approach bias may be more likely found in samples with low inhibitory control (e.g., overweight or obese individuals) than in the present sample (which had on average good inhibitory control). Taken together, the results confirm that attentional and approach biases are two distinctive types of cognitive bias, which is consistent with previous research in the alcohol domain (Sharbanee et al., 2013). Although both attentional and approach biases are components of automatic processing, the current findings suggest that approach bias may be more pertinent to understanding the association between food cues and eating behaviour. This may be due to the behavioural component of approach bias (i.e., moving towards or away from food cues) in addition to the cognitive one. However, future research needs to determine whether such findings apply to other appetitive substances, such as alcohol and cigarettes.

The present study also has some important practical implications. The results suggest that strong automatic tendencies to approach food cues as well as an inability to inhibit these responses can lead to unhealthy food intake. The current study used a healthy weight sample. It remains to be tested whether these findings apply to overweight and obese populations, who have been shown to have an approach bias for food (Havermans et al., 2011) and low inhibitory control (Nederkoorn et al., 2006a, Nederkoorn et al., 2006b). If so, the findings point the way toward a new form of intervention. Thus far, research has shown that automatic and controlled processes can be modified individually. For example, cognitive bias modification can be used to reduce approach biases for alcohol (Wiers et al., 2010; Wiers et al., 2011; Eberl et al., 2013) and chocolate (Kemps et al., 2013). Other research has shown that cognitive control training can increase inhibitory control for alcohol (Houben et al., 2011), food in general (Houben, 2011), and chocolate cues (Houben & Jansen, 2011). However, it is likely that the effectiveness of these interventions will differ among individuals and, as yet, the combined effect has not been investigated in any population. Thus, it would be useful to determine whether a combined approach leads to a better overall success rate in clinical samples. If so, this form of implicit training might provide a useful addition to existing treatments, such as cognitive-behavioural therapy, which target the explicit aspect of cognitive processing (MacLeod & Matthews, 2012; Wiers et al., 2013).

In summary, the present study has demonstrated that a particular combination of automatic and controlled processing predicts unhealthy food intake in young women. These findings are consistent with dual-process models, and contribute to an understanding of the mechanisms that underlie unhealthy eating behaviour. Accordingly, the results have practical implications in suggesting that interventions modify both automatic and controlled processing for maximal effectiveness in discouraging unhealthy food intake. This is particularly important in contemporary Western society, which is characterised by unhealthy eating behaviour.

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