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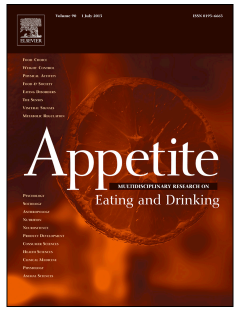

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Eating Behaviour Associated with Differences in Conflict Adaptation for Food Pictures

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Abstract

Objective: The goal conflict model of eating (Stroebe, Mensink, Aarts, Schut, & Kruglanski, 2008) proposes differences in eating behaviour result from peoples' experience of holding conflicting goals of eating enjoyment and weight maintenance. However, little is understood about the relationship between eating behaviour and the cognitive processes involved in conflict. This study aims to investigate associations between eating behaviour traits and cognitive conflict processes, specifically the application of cognitive control when processing distracting food pictures.

Method: A flanker task using food and non-food pictures was used to examine individual differences in conflict adaptation. Participants responded to target pictures whilst ignoring distracting flanking pictures. Individual differences in eating behaviour traits, attention towards target pictures, and ability to apply cognitive control through adaptation to conflicting picture trials were analysed.

Results: Increased levels of external and emotional eating were related to slower responses to food pictures indicating food target avoidance. All participants showed greater distraction by food compared to non-food pictures. Of particular significance, increased levels of emotional eating were associated with greater conflict adaptation for conflicting food pictures only.

Conclusion: Emotional eaters demonstrate greater application of cognitive control for conflicting food pictures as part of a food avoidance strategy. This could represent an attempt to inhibit their eating enjoyment goal in order for their weight maintenance goal to dominate.

Key Words: Attentional bias, conflict, food choice, eating behaviour, weight, cognitive control

Introduction

The goal conflict model of eating proposes that it is the conflict between automatic goals of eating enjoyment and controlled goals of behaviour change that explains rises in obesity and failures in weight-loss maintenance (Stroebe, van Koningsbruggen, Papies, & Aarts, 2013). However little is known about the cognitive processes involved in responding to these conflicting goals. Although research often focuses on conscious, observable behaviours or intentions, there is a need for non-conscious, automatic processes that influence behaviour to be more fully understood (Sheeran, Gollwitzer, & Bargh, 2013). Health behaviour can be manipulated by targeting non-conscious goals or cognitions (Papies & Hamstra, 2010; Wagner, Howland, & Mann, 2015). Further, successful dieters can adapt their cognitive control towards food (DelParigi et al., 2006, 2007; Papies & Hamstra, 2010; Papies, Stroebe, & Aarts, 2008; Stroebe et al., 2008). Therefore it is important to understand how we use cognitive control to adapt to conflicting food-related goals.

One factor that influences a person’s ability to maintain a healthy eating goal is the high level of food and food-related cues we are exposed to on a daily basis which are associated with differences in both eating behaviour and weight (Burgoine, Forouhi, Griffin, Wareham, & Monsivais, 2014; Cetateanu & Jones, 2014; Grafova, 2008; Kruger, Greenberg, Murphy, DiFazio, & Youra, 2014). These food cues introduce a conflict with some individuals responding to a heighted attentional bias for food that conflicts with their behavioural goal of sustained healthy eating (Herman & Polivy, 2008; Hou et al., 2011). This inability to apply cognitive control in order to ignore distraction by food cues has been suggested as a cause of disinhibited eating. Therefore this study will investigate the cognitive processes involved in controlling and adapting to food-related goal conflict by investigating the relationship between eating behaviour traits and the application of cognitive control.

Eating Behaviour and Cognition

Eating behaviour traits are representations of cognitive mechanisms that are adopted in response to conscious or unconscious behavioural goals. Restrained eating represents the cognitive restriction of food consumption, emotional eating represents the regulation of behavioural states using food, and external eating represents the motivational drive to consume food triggered by exposure to food cues. When reviewing the research on eating behaviour traits and cognition, the past focus has primarily been directed towards examining the relationship between restrained eating and cognition, specifically executive function and working memory (Jones & Rogers, 2003; Kemps & Tiggemann, 2005). The effects indicate a general cognitive impairment with a reduction in working memory capacity and impaired executive function (Brunstrom, Davison, & Mitchell, 2005; Higgs, 2007; Rogers & Green, 1993; Westenhoefer et al., 2013). More specifically, the ability to modulate attention towards food cues using working memory has been shown to be related to the capacity for an individual to apply effective dietary restraint (i.e. successful dieters) (Higgs, Dolmans, Humphreys, & Rutters, 2015). Findings demonstrate that food cues in particular have a strong effect on the top-down cognitive control processes that guide attention (Higgs, Rutters, Thomas, Naish, & Humphreys, 2012; Rutters, Kumar, Higgs, & Humphreys, 2015).

The literature on external eating and emotional eating behaviours and their connection with cognition, is sparser. There are some studies that have shown an attentional bias towards food cues related to increased external eating (Brignell, Griffiths, Bradley, & Mogg, 2009; Hou et al., 2011; Nijs, Franken, & Muris, 2009). Further, by its nature external eating is associated with an increased motivation to respond to palatable food cues in the environment, thus triggering disinhibited eating (Burton, Smit, & Lightowler, 2007; Kakoschke, Kemps, & Tiggemann, 2015). But alternatively, research has indicated that the attentional bias is driven more by changes in visual and reward-system activation as a result of weight-gain rather than eating behaviour trait (Castellanos et al., 2009; Stoeckel et al., 2008).

There is evidence to suggest that emotional eating is related to both avoidance of distraction and emotion-oriented coping (Spoor, Bekker, Van Strien, & van Heck, 2007). In turn it has been demonstrated that an avoidance orientation strategy enhances sustained cognitive control (Hengstler, Holland, van Steenbergen, & van Knippenberg, 2014). Approach and avoidance could be considered the two most fundamental motivation states, with avoidance motivation a means to prevent us from exposure to danger or negative outcomes (Elliot, 2008). In this instance the negative outcome is weight gain. Separately, research has shown that negative affect is associated with enhanced adaptation to conflict (Schuch & Kock, 2015; van Steenbergen, Band, & Hommel, 2010). Specifically, negative affect influences neural control processes when selecting task-relevant information, thereby reducing distraction (Melcher, Born, & Gruber, 2011). Emotional eating and negative affect are not the same thing, indeed a previous review demonstrated the difficulties around predicting how emotions affect eating (Macht, 2008). But, if this research is taken in combination, it suggests that increased levels of emotional eating may be associated with an avoidance motivation towards food and increased adaptation to conflicting goals for the food specific tasks.

Modulation of Cognitive Control

This study uses a flanker task (Eriksen & Eriksen, 1974) to focus on the cognitive conflict experienced when processing multiple food pictures and in particular the ability to adapt to that conflict. In a flanker task, a target stimulus is presented flanked on either side by non-target stimuli. Participants are instructed to make a response based on the target stimulus and to ignore the non-target stimuli. In congruent trials, target and non-target stimuli are the same. In incongruent trials, target and non-target stimuli differ in either the type of stimulus or the response required. Differences in ability to inhibit distraction and adapt to conflict are measured by comparing performance on congruent trials with incongruent trials (Eriksen & Eriksen, 1974; Eriksen & Schultz, 1979). This task differs from those used in previous studies in that it is not a working memory task or a specific task of attention. Instead it focuses on distraction and conflict. Therefore it is not clear if factors such as restraint seen in previous research on working memory and attention (e.g. Kemps & Tiggemann, 2005; Higgs, Dolmans, Humphreys, & Rutters, 2015) will also be influential in modulating conflict and cognitive control.

The cognitive process involved in the flanker task is typically explained with dual-route models consisting of a faster, automatic response route and a slower, more controlled route. If these routes trigger the same response (as with congruent trials) no conflict occurs. However if the routes trigger different response alternatives (as with incongruent trials) then the conflict needs to be resolved with top-down cognitive control, inhibiting the fast automatic route and responding with the slower, controlled route The difference in response times between congruent and incongruent conditions (the ‘flanker effect’) provides an index of the level of cognitive control exerted with larger flanker effects indicating greater distraction due to lower levels of cognitive control being successfully applied.

A second effect is that more cognitive control is applied in a trial if the preceding trial induced a conflict (Egner, 2007). It has been proposed that the application of cognitive control in the preceding trial results in a reduced flanker effect in the subsequent trial because the automatic processing route is inhibited (Clayson & Larson, 2011; Gratton, Coles, & Donchin, 1992; Ridderinkhof, 2002). By examining these trial by trial variations in the application of cognitive control, an individual’s ability to modulate the conflict being experienced can be measured.

Support for the successful use of the flanker task comes from both addiction research (Franken, van Strien, Franzek, & van de Wetering, 2007; Luijten, van Meel, & Franken, 2011), and from two prior food flanker studies (Forestell, Lau, Gyurovski, Dickter, & Haque, 2012; Meule, Vogele, & Kubler, 2012). Meule et al., (2012) proposed an association between restrained eating and an attentional bias towards food targets (as seen by faster reaction times to the food cues compared to the neutral cues). In contrast, Forestell el al., (2012) found no association between restrained eating and the flanker task performance when participants were satiated. However when hungry, restrained eaters did experience response conflict but only when low calorie food targets were flanked by high calorie distractors. In contrast, unrestrained eaters showed distraction by high calorie flankers for both low and high calorie food targets.

The overall goal of this research is to investigate associations between eating behaviour traits and the application and adaption of cognitive control. In the present study we used a flanker task in which participants were asked to respond to a target picture whilst ignoring flanking pictures, and examined the association between flanker effects and eating behaviour traits. In order to study the specific effects of food, we compared a food condition with a non-food condition. Within each of these conditions four pictures were used, two for each of the response categories. Target response categories were "sweet" and "savoury" for the food condition and "toy" and "bag" for the non-food condition. The sweet/savoury categorisation choice was selected as this is a comparatively objective distinction. Further the categorisations chosen replicated those used in previous research (Finlayson, King, & Blundell, 2007). A healthy/unhealthy categorisation would also be of interest[1], but the categorisation of healthy/unhealthy foods has been shown to be subjective (Falk, Sobal, Bisogni, Connors, & Devine, 2001). This could confound the manipulation if participants are

[1] We thank an anonymous reviewer for this suggestion.

not categorising the stimuli as intended. For example, chicken is not inherently healthy or unhealthy. This categorisation depends on overall diet.

In the congruent condition, the flanker pictures were from the same response category as the target picture whereas in the incongruent conditions they were not. The difference in response times between these is the flanker effect and indexes cognitive conflict. Based on the findings of previous flanker studies, we hypothesise that there will be a greater flanker effect in the incongruent conditions than the congruent condition, and a greater flanker effect in the food than the non-food condition. Although the previous food flanker findings are unclear, when the wider research on restraint and cognition is considered we hypothesise that restrained eating will be associated with an increased attention for food cues indicated by quicker reaction times for food pictures compared to non-food pictures. Reflecting an increased tendency for distraction by food stimuli in the environment, we hypothesise that external eating will be associated with greater distraction indicated by larger flanker effects for food pictures but not non-food pictures. Finally, drawing on the research on emotion, affect and avoidance motivation, we hypothesise that emotional eating will be associated with an avoidance of food cues indicated by slower reaction times to food than non-food pictures. Emotional eating will also be associated by greater adaptation to conflict indicated by a reduced flanker effect following an incongruent trial compared to a congruent trial for food pictures but not non-food pictures.

Method

Participants

Participants were recruited from the University of Surrey and the wider community using online advertising. Individuals were excluded from the study if they had been diagnosed with, or experienced any eating disorder, drug or alcohol addiction, diabetes, depression, epilepsy or other psychiatric or neurological condition. Due to the food pictures being presented, to avoid study sample related confounds, participants were screened out if they had food allergies or ate a vegetarian/vegan diet. This resulted in fifty participants taking part in the study. Three further participants were excluded from the analysis as their overall task response accuracy was below 80%. Of the 47 participants included in the final analysis, 87% were female and 13% male. The mean (M) age was 20 years (SD = 1.6 years). The participants mean BMI fell within the normal category weight range at 23.6 kg/m^2 (SD = 5.5).

Design

A within-subjects 2 x 3 experimental design was used with two picture conditions (food and non-food) and three levels of conflict (congruent, incongruent stimulus and incongruent response). In congruent (C) trials, target and flanker stimuli were the same. In incongruent stimulus (ICS) trials, target and flanker stimuli differed but were taken from the same response category. Finally, in incongruent response (ICR) trials, the target and flanker stimuli presented were different and triggered different responses. There was an equal number of each type of conflict trial. Each experimental condition consisted of four consecutive blocks of 96 randomised trials (total of 768 experimental trials).

Measures

Participants completed a number of self-report measures, which all demonstrated good internal consistency.

The *Dutch Eating Behaviour Questionnaire (DEBQ)* (Van Strien, Frijters, Bergers, & Defares, 1986) is a well-established and validated measure of eating behaviour trait. All sections of the DEBQ were used to allow the three eating behaviour traits of restraint, emotional eating and external eating to be examined. (Restraint $\alpha = .93$, Emotional eating $\alpha = .92$ and External eating $\alpha = .80$).

The *Positive Affect Negative Affect Schedule (PANAS)* (Watson, Clark, & Tellegen, 1988) was used to asses participants mood via their self-reported feelings of positive (PA) and negative affect (NA). This was included to help differentiate whether any associations seen were a result of individual differences in eating behaviour or affect. PANAS was administered twice (pre and post the experimental task) to first ascertain a participant State score (level of affect on the test day) and then subsequently to establish a Trait score (level of affect over preceding weeks). (PA $\alpha = .82$ and NA $\alpha = .87$).

7-point Likert scales measured individual differences in hunger, sleepiness and self-efficacy in weight-control. Likert scales ranging from 1 “very low” to 7 “very high”. Hedonic Liking was determined using the *Food Preference Checklist* taken from the *Leeds Food Choice Questionnaire* (Hill, Leathwood, & Blundell, 1987) and a hedonic liking scale. These measures were included to allow analysis of possible confounding factors that could be influential on interpreting outcomes.

Stimulus Validation

The stimuli used in the task were from the Foodcast Research Image Database (Foroni, Pergola, Argiris, & Rumiati, 2013). Each image is provided by the Foodcast database with spatial frequency and luminance values as well as validated population ratings for factors such as valence, familiarity and recognition. Study participants reviewed both the pictures used in the experiment and an additional sample of picture stimuli to ensure there was no discrepancy between the study participant ratings and the original validated ratings. Study participant ratings were based on a 9-point Likert scale. Participants mean valence scores were 4.82 ± 0.8 for non-food and 6.74 ± 1.4 for food pictures. To minimise confounding variables created by perceptual stimulus differences in spatial frequency and luminance, stimuli were matched across conditions. Paired t-tests confirmed no significant group differences for spatial frequency $t(6) = .684$, $p = .53$ or luminance $t(6) = .514$, $p = .62$.

Procedure

All participants had normal or corrected to normal vision. All testing took place in a windowless room with controlled lighting to ensure conditions were consistent across participants. Eligible participants were entitled to claim two lab tokens as part of an undergraduate research participation scheme. Participants were given a brief overview of the study and after obtaining informed consent, the State PANAS, and first set of Likert scales were administered. Participants then undertook the experimental task.

The experimental task was programmed in e-Prime 2.0. Screen resolution on the display was 1024 x 768 and the refresh rate was 60 Hz. Participants completed a training block of 12 trials at the beginning of each condition which provided performance feedback on both accuracy and speed of response. Participants had the opportunity for breaks between blocks to avoid experimental fatigue. Participants were instructed to respond to the centrally presented target stimulus as quickly and accurately as possible, while ignoring flanking distractor stimuli (See Fig. 1). The pictures used were: breast of chicken, lasagne, fruit salad and chocolate for the food condition and Teddy Bear, Windmill, briefcase and wash bag for the non-food condition. Participants could make their response choice, by pressing one of two set finger response keys (Z/M) using their index fingers. Participation order for each condition was counterbalanced across participants, as was the stimulus category response key assignment.

Suggest insert Fig.1 here -

Participants were positioned 60cm from the display monitor. Individual images used were all 133x133 pixels with a visual angle of 5.5°x 4.5° with all 9 images presented in grid form creating a total visual angle of 16.5° x 13.5°. The trial started with the presentation of a fixation cross (See fig.2). All stimuli were presented on a white background. In each trial the flanking stimuli were presented for 100ms before the central target stimulus was added to the display. Both flanker and target stimuli then remained on the screen for 150ms after target onset and were replaced by the display of a fixation cross for 1750ms between trials. The inter trial interval was 2000ms.

Suggest insert Fig. 2 here -

Following the experiment the remaining questionnaire measures and Likert scales were completed and the participant debrief undertaken. All procedures were subject to ethical approval that was obtained from the University of Surrey ethics committee and carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Data Analysis

For the flanker task correct participant responses were included where reaction times were between 150-1000ms post target presentations. Responses recorded less than 150ms after target onset are anticipation responses, with responses given post 1000ms viewed as a late response (Eriksen & Eriksen, 1974; Eriksen & Schultz, 1979; Gratton, Coles, & Donchin, 1992). Analysis was only conducted when the previous trial was correct to ensure there was no post-error slowing effect confounding results (Dutilh et al., 2012; Rabbitt & Rodgers, 1977). Flanker effects (FE) were calculated by subtracting the mean values for the congruent trials from mean values of the incongruent stimulus trials (FE-ICS) and incongruent response trials (FE-ICR). A more positive FE would indicate a participant has experienced greater distraction by the conflicting flanker pictures and been slower to correctly respond to the target picture.

For the statistical analysis of RT and FE, repeated measures ANOVAs were used. In the event of a violation of the sphericity assumption, the Huynh-Feldt statistic was adopted. Post hoc t-tests were conducted and Bonferroni corrections applied.

To determine individual differences in conflict adaptation a cognitive control modulation (CCM) score was calculated. This was achieved by calculating the difference in FE-ICRs when preceded by congruent trials (no conflict in the previous trial) and the FE-ICR when preceded by other incongruent response trials (conflict is present in the previous trial). For example, if a participant's mean flanker effect for incongruent response trials with no prior conflict trial was 82ms and the mean flanker effect for incongruent response trials where the preceding trial was also a conflict trial was 56ms, the cognitive control modulation score would be 26. The greater the difference between the two flanker effects, the more effective the cognitive conflict adaptation. That is, a more positive the CCM score reflects the ability of the participant to adapt or modulate their cognitive control in relation to fast environmental changes.

Finally, a correlational analysis assessed the relationship between the experimental measures such as overall RTs, FEs and CCM scores, and individual differences in eating behaviour trait.

Results

Cognitive Conflict

In order to examine the general hypothesis that there will be a sequential increase in the cognitive conflict experienced for trials with conflicting target and flanker pictures, a repeated measures 2 x 3 x 3 ANOVA with the factors condition (Food v Non-Food), current trial type (C v ICS v ICR), and previous trial (C v ICS v ICR) was conducted. The results showed no significant main effect of picture condition $F(1,46) = 3.40$, $p = .072$, $\eta_p^2 = .07$. There was a significant main effect for current trial type $F(2,92) = 634.14$, $p < .001$, $\eta_p^2 = .93$. Specifically, responses to the congruent trials (M = 441 SD = 51ms) were faster than the incongruent stimulus (ICS) trials (M = 480 SD = 46ms), $t(46) = 18.83$, $p < .001$, and responses to incongruent stimulus trials were faster than the incongruent response (ICR) trials

(522 ± 44ms) $t(46) = 18.84$, $p < .001$. Thus the predicted increase in level of conflict, from congruent through ICS to ICR, was seen through a significant slowing in participant response.

Some further analysis was undertaken however as a significant interaction between the factors of picture condition and current trial type was identified $F(2, 92) = 8.13$, $p = .001$, $\eta_p^2 = .15$ (see fig. 3). The post hoc tests indicated no significant difference between reaction times for the food and non-food pictures in the congruent conditions, $t(46) = .206$, $p = .838$, meaning participants were not reacting differently across conditions when no conflict was present. But there were slower reaction times for the food pictures, compared to the non-food pictures, as conflict was introduced, ICS trials, $t(46) = 2.69$ $p = .01$; ICR trials, $t(46) = 2.55$, $p = .029$, (*NB the latter comparison is borderline significant after Bonferroni correction based on $p_{corrected} = .025$). Therefore in addition to the general sequential increase in conflict that was established, the results do indicate the level of conflict was greater in the food condition compared to the non-food condition.

Suggest insert fig. 3 here -

Modulation of Cognitive Control

The second element of the analysis was to determine whether there was evidence for participants modulating their level of cognitive control. The ANOVA did indicate a significant main effect of previous trial type $F(2,92) = 40.96$, $p < .001$, $\eta_p^2 = .47$ as well as a significant interaction between the previous trial type and current trial type $F(4, 184) = 13.51$, $p < .001$, $\eta_p^2 = .23$. This means that the flanker effect magnitude was modulated by the previous trial type. The absence of a significant three-way interaction between picture condition, current trial and previous trial signifies the conflict adaptation process itself did not differ between conditions ($F(4, 184) = 1.88$, $p =.116$, $\eta_p^{2\,=}$ .04).

As illustrated in figure 4, a significant reduction in distraction by flankers for incongruent response trials (FE-ICR) was seen if the previous trial had also been an ICR trial compared to when the previous trial was congruent $t(46) = 6.70$, $p < .001$. There was also a significant reduction in FE-ICR if the previous trial had been an ICR trial compared to when the previous trial was an ICS trial, $t(46) = 3.72$, $p = .001$. Finally, there was a significant reduction in flanker effects for incongruent stimulus trials (FE-ICS) if the previous trial was also an ICS trial compared to when the previous trial was congruent, $t(46) = 3.77$, $p < .001$. All these results confirm that when the previous trial was a conflict trial, there was a modulation in the level of cognitive control being applied to the subsequent trial, this increase in cognitive control then causes a reduction in level of distraction.

Suggest insert figure 4 here

Eating Behaviour and Cognitive Control

The final level of analysis was to address the three eating behaviour hypotheses and examine whether there was evidence for a relationship between eating behaviour traits and the cognitive processes involved in the flanker task. Participants' eating behaviour trait scores were correlated with reaction times, flanker effects and conflict adaptation scores and are shown in table 1.

- *Suggest insert table 1 here* -

The results show that both higher external eating and emotional eating behaviour traits were associated with significantly slower responses in the food condition but not the non-food condition. However increased restrained eating trait was not associated with an attentional bias towards food targets. Of particular interest however, the cognitive control modulation score shows a significant positive association with increased levels of emotional eating trait. But the finding that emotional eaters demonstrated greater levels of conflict adaptation was only significant for the food condition.

Participants' mood on the day of testing was related to the level of distraction by flanking pictures. Increased levels of state positive affect were associated with increased flanker effects whereas negative affect was negatively correlated with overall flanker effect size. There was no significant relationship evident with trait affect. Associations between possible confounding factors of hunger, sleepiness, self-efficacy in weight-control, hedonic liking for food, or picture valence and the experimental variables were examined and no significant correlations were present.

Discussion

Considering principles proposed by the goal conflict model of eating (Stroebe, Mensink, Aarts, Schut, & Kruglanski, 2008) of the rise in obesity being driven by peoples' experience of holding conflicting goals of eating enjoyment and weight maintenance, the aim of this research was to investigate associations between eating behaviour traits and cognitive conflict processes, specifically the application of cognitive control required when processing distracting food pictures. The general hypothesis that there would be a sequential increase in conflict rising from congruent, through stimulus incongruent to response incongruent trials was supported. The hypothesis that restraint would be related to an increased attentional bias towards food targets was not supported but there were indications of differences in emotional and external eating behaviour response to food. Both emotional and external eating behaviour were associated with a slower reaction to food targets, although the predicted increased distraction by food flankers for external eaters was not present. The key finding of the study however was that increased emotional eating trait behaviour was significantly associated with greater application of cognitive control but in response to food conflict trials only.

Slower reaction times can be taken as indications of attempts to direct attention away from the target stimulus (Veenstra, de Jong, Koster, & Roefs, 2010). Participants reporting increased trait tendency for emotional and external eating behaviour were significantly slower to respond to the food targets. Prior reviews have shown that individuals can show avoidance strategies for items that have a negative motivational aspect (Laricchiuta & Petrosini, 2014). The avoidance system reflecting an attentional system that promotes appetitive response inhibition or potentially active overt withdrawal (Carver & Miller, 2006; Pickering & Gray, 2001). Further, avoidance has been indicated as a coping strategy to reduce food intake (Spoor et al., 2007). If we consider this prior literature, the reaction time results could support the suggestion that the food target pictures have negative salience for both emotional and external eaters and therefore trigger attempts at avoidance. Further support for this theory is found in previous research where attempts at attentional avoidance and adoption of cognitive strategies to reduce the maintenance of attention towards food have been seen (Nijs et al., 2010; Veenstra et al., 2010). It is recognised that the complex evidence surrounding attentional bias for food indicates a number of different processes involved, which in turn drive a range of different behavioural responses (Corbetta & Shulman, 2002; Hendrikse et al., 2015). What is known however is that an avoidance orientation strategy can enhance sustained cognitive control (Hengstler et al., 2014). What is interesting is that this particular aspect of cognitive control is only evident in individuals with increased emotional eating trait, and only in relation to the food pictures.

The results suggests that those individuals who are higher in emotional eating more effectively respond to processing conflicting food stimuli and as a result inhibit their reliance on automatic processing responses. Enhanced cognitive control modulation is present for food but not non-food stimuli and as such demonstrates a food specific, as opposed to a general, cognitive ability. The relationship between emotional eating and conflict adaptation was hypothesised based on the previous research suggesting an ability to apply goal-directed cognitive control required in conflict adaptation is heightened for negative states (Schuch & Kock, 2015; van Steenbergen et al., 2010). Emotional eating behaviour is in turn associated with disinhibited eating when experiencing a variety of negative emotional states (Ganley, 1989; Van Strien, Frijters, Bergers, & Defares, 1986). Our assumption was that this could translate into cognitive processing of food pictures that reflects a negativity emotional reaction as discussed above, an avoidance strategy. It is recognised that emotional eating is not the same as being in a negative state and indeed although the participants' mood on the day (state affect) was shown to be influential on an ability to inhibit distracting stimuli, the result was only significant with respect to overall flanker effects (general level of distraction) rather than conflict adaptation. The comprehensive review by Macht (2008) highlights that positive and negative emotions as well as behavioural, cognitive and physiological differences all affect emotional eating behaviour. Therefore it is perhaps too early to try and find a simplistic reason for the results seen, but avoidance motivation does appear to provide a coherent theoretical explanation.

It is important to emphasise that when we refer to individuals as having adopted a controlled cognitive strategy we do not mean they have done this consciously. With dual-processing models the terms automatic and controlled are often associated with unconscious and conscious processing, when in fact they are not interchangeable. The principle of automaticity is best viewed as operating on a continuum, as opposed to being a particular state of awareness (Evans, 2009). In the specific context here, the processing pathways that are being discussed operate at a unconscious level with the controlled response occurring on average within 500ms. Therefore we are not suggesting that individuals are aware of the processing pathways and switching between them when experiencing conflict from food stimuli. Instead, that it is an ability that has either developed over time (in an attempt to aid weight maintenance and counter-act their heightened automatic motivation to consume food or overeat in certain physiological states), or alternatively it is an innate aspect of cognitive processing that is present in emotional eating behaviour trait that only fails under certain circumstances.

Consideration was given as to why either a similar pattern of enhanced cognitive control or indeed the hypothesised enhanced distraction for external eaters was not found. Previous research has shown that the level of distraction by flankers is reduced for participants whose response to target stimuli is slower (Sanders & Lamers, 2002). Therefore the adoption of a target avoidance approach could simply explain why external eating was not associated with increased distraction as indicated by flanker effects. However it does not explain why there was not a similar enhancement of cognitive control in response to the conflicting trials, and at this stage it is perhaps unwise to try and speculate.

In relation to the lack of relationship with restraint, although our hypothesis was based on previous findings (Forestell et al., 2012; Meule et al., 2012), the fact that no significant relationship was evident is perhaps in hindsight not that surprising. Firstly, Meule et al., 2012 found restrained eating was related to a heightened reaction to high caloric foods only. In contrast the food pictures used in this study were taken from across the spectrum of high/low fat and sugar groups and therefore any bias may only be evident at extremes of palatability/calorie content. But additionally, Forestell et al. found a relationship between restraint and response conflict only when participants were hungry and even here the association did not have a straightforward linear relationship. It is also important to note that in the prior research examining the relationship between restraint and working memory guidance of attention to food cues, it was the combination of restraint and disinhibition that was key to the association (Higgs et al., 2015) which was not assessed in this study. Taken together the findings could imply that either restrained eating behaviour may not be key to understanding variation in this specific cognitive conflict process or that it is differences in restraint in combination with other trait behaviours that is relevant. The exact nature of any association requires further investigation. Furthermore, although previous research examining restraint and cognition has established indications of a deficit in working memory capacity, the flanker task is not a working memory task. Therefore the difference in task process between studies could be a simple explanation for the lack of similar findings to prior research (Higgs et al., 2015; 2012).

Although the experimental design and controls applied to the study are robust and therefore the methodological aspects of the study are strong, there are limitations that need to be acknowledged. The research is undertaken in a relatively small sample and therefore it is not appropriate to make strong generalisations to the wider population. In addition, the findings for the eating behaviour traits are based on correlational data and therefore we cannot determine either the direction of the relationship with the experimental results or their stability over time. As a result it is important to interpret some of the suggestions offered here with some caution. There is a need to try and separate out eating behaviour traits more definitively in order to ascertain specifically which aspects of eating behaviour are influential in cognitive processing of food and cognitive conflict in particular. It would be beneficial to both replicate these findings and to investigate whether individuals who are higher in emotional eating apply this strategy only at times of high resilience, for example when satiated. Finally it would be interesting to note whether different patterns of eating, for example calorie restriction in comparison to occasional fasting, are influential on an individual’s ability to maintain cognitive control and therefore are more effective as a means of long-term weight maintenance.

In conclusion, the findings provide some support for the goal conflict model of eating and the principle that eating behaviour trait is associated with the level of cognitive conflict experienced as a result of food distraction in the environment. In response to conflict participants demonstrated modulation in cognitive control as proposed by dual-process models. Individual differences in conflict adaptation were positively correlated to emotional eating behaviour in the food condition but not the non-food condition. This indicates that individuals higher in emotional eating were better at applying cognitive control and inhibiting distracting food pictures. Further investigation is required in order to test some theoretical explanations for the findings and to examine whether increased ability for cognitive control is sustained in different states.

Authors confirm that there is no conflict of interest to declare in relation to this submission.

References

Brignell, C., Griffiths, T., Bradley, B. P., & Mogg, K. (2009). Attentional and approach biases for pictorial food cues. Influence of external eating. *Appetite*, *52*(2), 299–306. http://doi.org/10.1016/j.appet.2008.10.007

Brunstrom, J. M., Davison, C. J., & Mitchell, G. L. (2005). Dietary restraint and cognitive performance in children. *Appetite*, *45*(3), 235–41. doi.org/10.1016/j.appet.2005.07.008

Burgoine, T., Forouhi, N. G., Griffin, S. J., Wareham, N. J., & Monsivais, P. (2014). Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK: population based, cross sectional study. *BMJ (Clinical Research Ed.)*, *348*, g1464. doi.org/10.1136/bmj.g1464

Burton, P., Smit, H. J., & Lightowler, H. J. (2007). The influence of restrained and external eating patterns on overeating. *Appetite*, *49*(1), 191–7. doi.org/10.1016/j.appet.2007.01.007

Carver, C. S., & Miller, C. J. (2006). Relations of serotonin function to personality: current views and a key methodological issue. *Psychiatry Research*, *144*(1), 1–15. doi.org/10.1016/j.psychres.2006.03.013

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., & Cowan, R. L. (2009). Obese adults have visual attention bias for food cue images: evidence for altered reward system function. *International Journal of Obesity*, *33*(9), 1063–1073. doi.org/Doi 10.1038/Ijo.2009.138

Cetateanu, A., & Jones, A. (2014). Understanding the relationship between food environments, deprivation and childhood overweight and obesity: evidence from a cross sectional England-wide study. *Health & Place*, *27*, 68–76. doi.org/10.1016/j.healthplace.2014.01.007

Clayson, P. E., & Larson, M. J. (2011). Conflict adaptation and sequential trial effects: support for the conflict monitoring theory. *Neuropsychologia*, *49*(7), 1953–61. doi.org/10.1016/j.neuropsychologia.2011.03.023

Cohen, J. (1992). Statistical Power Analysis. *Current Directions in Psychological Science*, *1*(3), 98–101. doi.org/10.1111/1467-8721.ep10768783

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews. Neuroscience*, *3*(3), 201–215. doi.org/10.1038/nrn755

DelParigi, A., Chen, K., Salbe, A. D., Hill, J. O., Wing, R. R., Reiman, E. M., & Tataranni, P. A. (2007). Successful dieters have increased neural activity in cortical areas involved in the control of behavior. *International Journal of Obesity (2005)*, *31*(3), 440–8. doi.org/10.1038/sj.ijo.0803431

DelParigi, A., Gautier, J.-F., Chen, K., Salbe, A. D., Ravussin, E., Reiman, E., & Tatarranni, P. A. (2006). Neuroimaging and Obesity. *Annals of the New York Academy of Sciences*, *967*(1), 389–397. doi.org/10.1111/j.1749-6632.2002.tb04294.x

Egner, T. (2007). Congruency sequence effects and cognitive control. *Cognitive, Affective & Behavioral Neuroscience*, *7*(4), 380–390. doi:10.3758/CABN.7.4.380

Elliot, A. J. (2008). *Handbook of Approach and Avoidance Motivation*. (A. J. Elliot, Ed.), *Psychology Press*. Taylor & Francis Group. doi.org/10.1017/CBO9781107415324.004

Eriksen, B., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143–149. doi.org/10.3758/BF03203267

Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception & Psychophysics, 25*(4), 249–263. doi.org/10.3758/BF03198804

Evans, J. T., & Frankish, K. (2009). *In two minds: Dual processes and beyond.* New York, US: Oxford University Press.

Falk, L. W., Sobal, J., Bisogni, C. A., Connors, M., & Devine, C. M. (2001). Managing Healthy Eating: Definitions, Classifications, and Strategies. *Health Education & Behavior*, *28*(4), 425–439. doi.org/10.1177/109019810102800405

Finlayson, G., King, N., & Blundell, J. E. (2007). Is it possible to dissociate “liking” and “wanting” for foods in humans? A novel experimental procedure. *Physiology & Behavior*, *90*(1), 36–42. doi.org/10.1016/j.physbeh.2006.08.020

Forestell, C. A., Lau, P., Gyurovski, I. I., Dickter, C. L., & Haque, S. S. (2012). Attentional biases to foods: The effects of caloric content and cognitive restraint. *Appetite*, *59*(3), 748–754. doi.org/10.1016/j.appet.2012.07.006

Foroni, F., Pergola, G., Argiris, G., & Rumiati, R. I. (2013). The FoodCast research image database (FRIDa). *Frontiers in Human Neuroscience*, *7*, 51. doi.org/10.3389/fnhum.2013.00051

Franken, I. H., van Strien, J. W., Franzek, E. J., & van de Wetering, B. J. (2007). Error-processing deficits in patients with cocaine dependence. *Biological Psychology*, *75*(1), 45–51. doi.org/10.1016/j.biopsycho.2006.11.003

Ganley, R. M. (1989). Emotion and eating in obesity: A review of the literature. *International Journal of Eating Disorders*, *8*(3), 343–361. doi.org/10.1002/1098-108X(198905)8:3<343::AID-EAT2260080310>3.0.CO;2-C

Grafova, I. B. (2008). Overweight children: assessing the contribution of the built environment. *Preventive Medicine, 47*(3), 304–308.

Gratton, G., Coles, M. G., & Donchin, E. (1992). Optimizing the use of information: strategic control of activation of responses. *Journal of Experimental Psychology. General, 121*(4), 480–506. doi:10.1037/0096-3445.121.4.480

Hendrikse, J. J., Cachia, R. L., Kothe, E. J., McPhie, S., Skouteris, H., & Hayden, M. J. (2015). Attentional biases for food cues in overweight and individuals with obesity: a systematic review of the literature. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*. doi.org/10.1111/obr.12265

Hengstler, M., Holland, R. W., van Steenbergen, H., & van Knippenberg, A. (2014). The influence of approach-avoidance motivational orientation on conflict adaptation. *Cognitive, Affective & Behavioral Neuroscience*, *14*(2), 548–60. doi.org/10.3758/s13415-014-0295-6

Herman, C. P., & Polivy, J. (2008). External cues in the control of food intake in humans: The sensory-normative distinction. *Physiology & Behavior*, *94*(5), 722–728. doi.org/10.1016/j.physbeh.2008.04.014

Higgs, S. (2007). Impairment of cognitive performance in dietary restrained women when imagining eating is not affected by anticipated consumption. *Eating Behaviors*, *8*(2), 157–61. doi.org/10.1016/j.eatbeh.2006.03.004

Higgs, S., Dolmans, D., Humphreys, G. W., & Rutters, F. (2015). Dietary self-control influences top-down guidance of attention to food cues. *Frontiers in Psychology, 6*, 427. doi.org/10.3389/fpsyg.2015.00427

Higgs, S., Rutters, F., Thomas, J. M., Naish, K., & Humphreys, G. W. (2012). Top down modulation of attention to food cues via working memory. *Appetite*, *59*(1), 71–5. doi.org/10.1016/j.appet.2012.03.018

Hou, R., Mogg, K., Bradley, B. P., Moss-Morris, R., Peveler, R., & Roefs, A. (2011). External eating, impulsivity and attentional bias to food cues. *Appetite*, *56*(2), 424–427. doi.org/10.1016/j.appet.2011.01.019

Jones, N., & Rogers, P. J. (2003). Preoccupation, food, and failure: an investigation of cognitive performance deficits in dieters. *The International Journal of Eating Disorders*, *33*(2), 185–92. doi.org/10.1002/eat.10124

Kakoschke, N., Kemps, E., & Tiggemann, M. (2015). External eating mediates the relationship between impulsivity and unhealthy food intake. *Physiology & Behavior*, *147*, 117–21. doi.org/10.1016/j.physbeh.2015.04.030

Kemps, E., & Tiggemann, M. (2005). Working memory performance and preoccupying thoughts in female dieters: evidence for a selective central executive impairment. *The British Journal of Clinical Psychology / the British Psychological Society*, *44*(Pt 3), 357–66. doi.org/10.1348/014466505X35272

Kruger, D. J., Greenberg, E., Murphy, J. B., DiFazio, L. A., & Youra, K. R. (2014). Local concentration of fast-food outlets is associated with poor nutrition and obesity. *American Journal of Health Promotion : AJHP*, *28*(5), 340–3. doi.org/10.4278/ajhp.111201-QUAN-437

Laricchiuta, D., & Petrosini, L. (2014). Individual differences in response to positive and negative stimuli: endocannabinoid-based insight on approach and avoidance behaviors. *Frontiers in Systems Neuroscience*, *8*, 238. doi.org/10.3389/fnsys.2014.00238

Luijten, M., van Meel, C. S., & Franken, I. H. (2011). Diminished error processing in smokers during smoking cue exposure. *Pharmacology, Biochemistry, and Behavior*, *97*(3), 514–520. hdoi.org/10.1016/j.pbb.2010.10.012

Macht, M. (2008). How emotions affect eating: a five-way model. *Appetite*, *50*(1), 1–11.

doi.org/10.1016/j.appet.2007.07.002

Melcher, T., Born, C., & Gruber, O. (2011). How negative affect influences neural control processes underlying the resolution of cognitive interference: an event-related fMRI study. *Neuroscience Research*, *70*(4), 415–27. doi.org/10.1016/j.neures.2011.05.007

Meule, A., Vogele, C., & Kubler, A. (2012). Restrained eating is related to accelerated reaction to high caloric foods and cardiac autonomic dysregulation. *Appetite*, *58*(2), 638–644. doi.org/10.1016/j.appet.2011.11.023

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2009). Enhanced processing of food-related pictures in female external eaters. *Appetite*, *53*(3), 376–383. doi.org/10.1016/j.appet.2009.07.022

Nijs, I. M. T., Muris, P., Euser, A. S., & Franken, I. H. A. (2010). Differences in attention to food and food intake between overweight/obese and normal-weight females under conditions of hunger and satiety. *Appetite*, *54*(2), 243–254. doi.org/10.1016/j.appet.2009.11.004

Papies, E. K., & Hamstra, P. (2010). Goal Priming and Eating Behavior: Enhancing Self-Regulation by Environmental Cues. *Health Psychology*, *29*(4), 384–388. doi.org/10.1037/a0019877

Papies, E. K., Stroebe, W., & Aarts, H. (2008). Healthy cognition: Processes of self-regulatory success in restrained eating. *Personality and Social Psychology Bulletin*, *34*(9), 1290–1300. doi.org/10.1177/0146167208320063

Pickering, A. D., & Gray, J. A. (2001). Dopamine, appetitive reinforcement and the neuropsychology of human learning: an individual differences approach. In A. Angleitner (Ed.), *Advances in Individual Differences Research* (pp. 113–149). Lengerich, Germany: PABST Science Publishers.

Rabbitt, P., & Rodgers, B. (1977). What does a man do after he makes an error? an analysis of response programming. *Quarterly Journal of Experimental Psychology*, *29*(4), 727–743. doi.org/10.1080/14640747708400645

Ridderinkhof, K. R. (2002). Micro- and macro-adjustments of task set: activation and suppression in conflict tasks. *Psychological Research*, *66*(4), 312–23. doi.org/10.1007/s00426-002-0104-7

Rogers, P. J., & Green, M. W. (1993). Dieting, dietary restraint and cognitive performance. *The British Journal of Clinical Psychology / the British Psychological Society*, *32 (Pt 1)*, 113–6.

Rutters, F., Kumar, S., Higgs, S., & Humphreys, G. W. (2015). Electrophysiological evidence for enhanced representation of food stimuli in working memory. *Experimental Brain Research*, *233*(2), 519–28. doi.org/10.1007/s00221-014-4132-5

Sanders, A, & Lamers, J. (2002). The Eriksen flanker effect revisited. *Acta Psychologica*, *109*(1), 41–56. doi.org/10.1016/S0001-6918(01)00048-8

Schuch, S., & Kock, I. (2015). Mood states influence cognitive control: the case of conflict adaptation. *Psychological Research*, *79*, 759–772. doi.org/10.1007/s00426-014-0602-4

Sheeran, P., Gollwitzer, P. M., & Bargh, J. A. (2013). Nonconscious processes and health. *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association*, *32*(5), 460–73. doi.org/10.1037/a0029203

Sokhadze, E., Stewart, C., Hollifield, M., & Tasman, A. (2008). Event-Related Potential Study of Executive Dysfunctions in a Speeded Reaction Task in Cocaine Addiction. *Journal of Neurotherapy*, *12*(4), 185–204. doi.org/10.1080/10874200802502144

Spoor, S. T. P., Bekker, M. H. J., Van Strien, T., & van Heck, G. L. (2007). Relations between negative affect, coping, and emotional eating. *Appetite*, *48*(3), 368–76. doi.org/10.1016/j.appet.2006.10.005

Stoeckel, L. E., Weller, R. E., Cook, E. W., Twieg, D. B., Knowlton, R. C., & Cox, J. E. (2008). Widespread reward-system activation in obese women in response to pictures of high-calorie foods. *Neuroimage*, *41*(2), 636–647.doi. 10.1016/j.neuroimage.2008.02.031

Stroebe. (2008). *Dieting, overweight, and obesity : self-regulation in a food-rich environment* (1st ed.). Washington, DC ; London: American Psychological Association.

Stroebe, Mensink, W., Aarts, H., Schut, H., & Kruglanski, A. W. (2008). Why dieters fail: Testing the goal conflict model of eating. *Journal of Experimental Social Psychology*, *44*(1), 26–36. doi.org/10.1016/j.jesp.2007.01.005

Stroebe, W., van Koningsbruggen, G. M., Papies, E. K., & Aarts, H. (2013). Why most dieters fail but some succeed: a goal conflict model of eating behavior. *Psychological Review*, *120*(1), 110–38. doi.org/10.1037/a0030849

van Steenbergen, H., Band, G. P. H., & Hommel, B. (2010). In the mood for adaptation: how affect regulates conflict-driven control. *Psychological Science*, *21*(11), 1629–34. doi.org/10.1177/0956797610385951

Van Strien, T., Frijters, J. E. R., Bergers, G. P. A., & Defares, P. B. (1986). The Dutch Eating Behaviour Questionnaire (DEBQ) for assessment of restrained, emotional and external eating behaviour. *International Journal of Eating Disorders*, *5*(2), 295–315.

Veenstra, E. M., de Jong, P. J., Koster, E. H. W., & Roefs, A. (2010). Attentional avoidance of high-fat food in unsuccessful dieters. *Journal of Behavior Therapy and Experimental Psychiatry*, *41*(3), 282–288. doi.org/10.1016/j.jbtep.2010.02.006

Wagner, H. S., Howland, M., & Mann, T. (2015). Effects of subtle and explicit health messages on food choice. *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association*, *34*(1), 79–82. doi.org/10.1037/hea0000045

Westenhoefer, J., Engel, D., Holst, C., Lorenz, J., Peacock, M., Stubbs, J., … Raats, M. (2013). Cognitive and weight-related correlates of flexible and rigid restrained eating behaviour. *Eating Behaviors*, *14*(1), 69–72. http://doi.org/10.1016/j.eatbeh.2012.10.015

Tables

Table 1

Summary of correlations between eating behaviour traits, affect and reaction times (RT), flanker effects (FE) and cognitive control modulation (CCM)

	RT for food	**RT for non-food**	**FE for food**	**FE for non-food**	**CCM Food**	**CCM Non-food**
Emotional	**.303***	.284	-.045	-.238	**.294***	.085
External	**.316***	.227	-.144	-.094	.097	-.177
Restraint	.157	.048	-.026	-.166	.065	.045
Positive Affect	-.038	-.129	.189	**.295***	.098	.185
Negative Affect	.223	.266	-.193	**-.324***	.244	.185

***= P < .05 **= p < .005** correlation for state negative and positive affect scores shown.

Figures

Fig. 1 Example of an ICR food trial (sweet target and savoury flankers) and an ICS non-food trial (bag target and contrasting bag flankers).

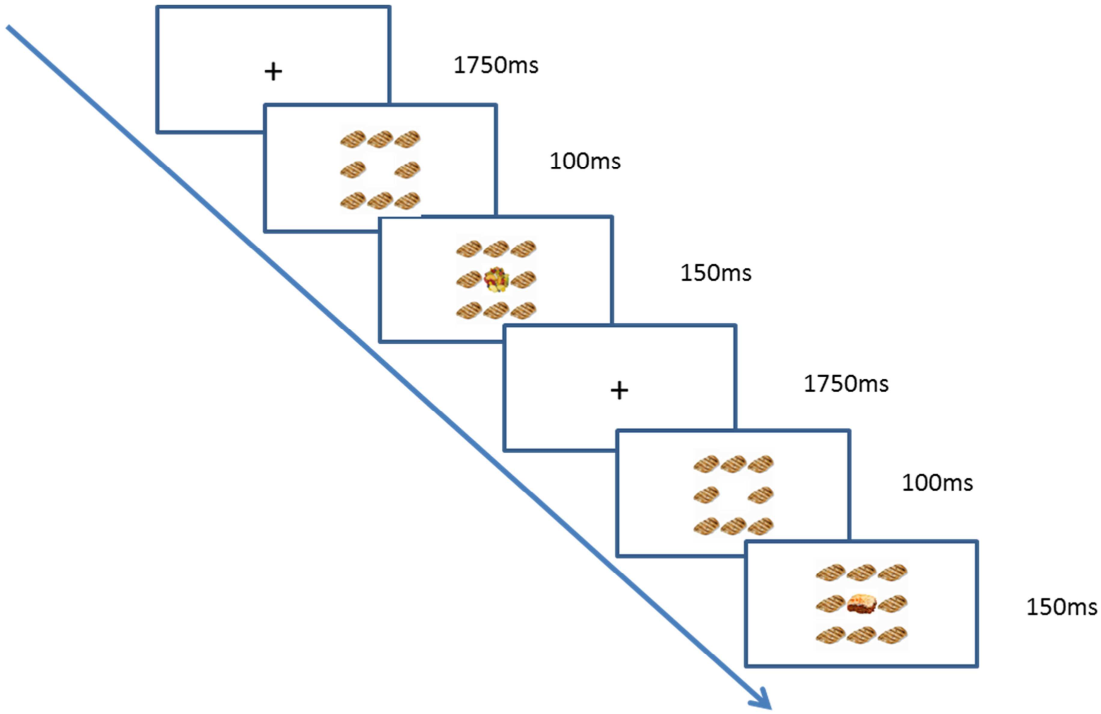

Fig. 2 Representation of the trial procedure using an ICR and ICS food trial sequence.

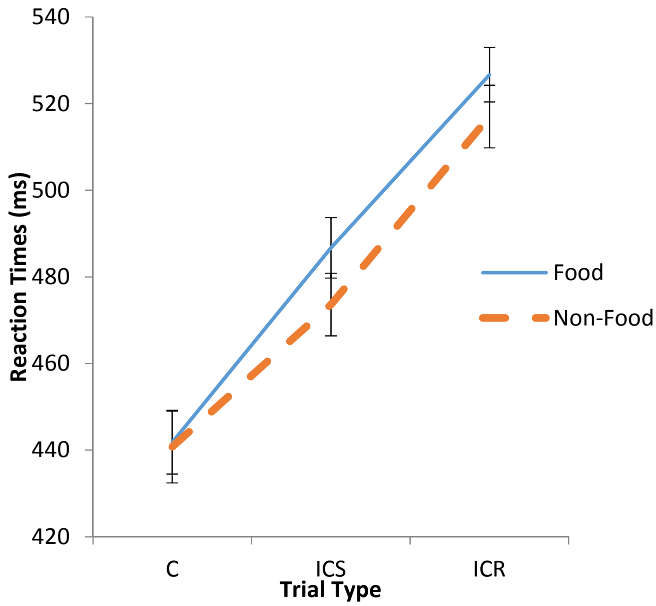

Fig. 3 Reaction time interaction of trial type (C vs ICS v ICR) and condition (food and non-food).

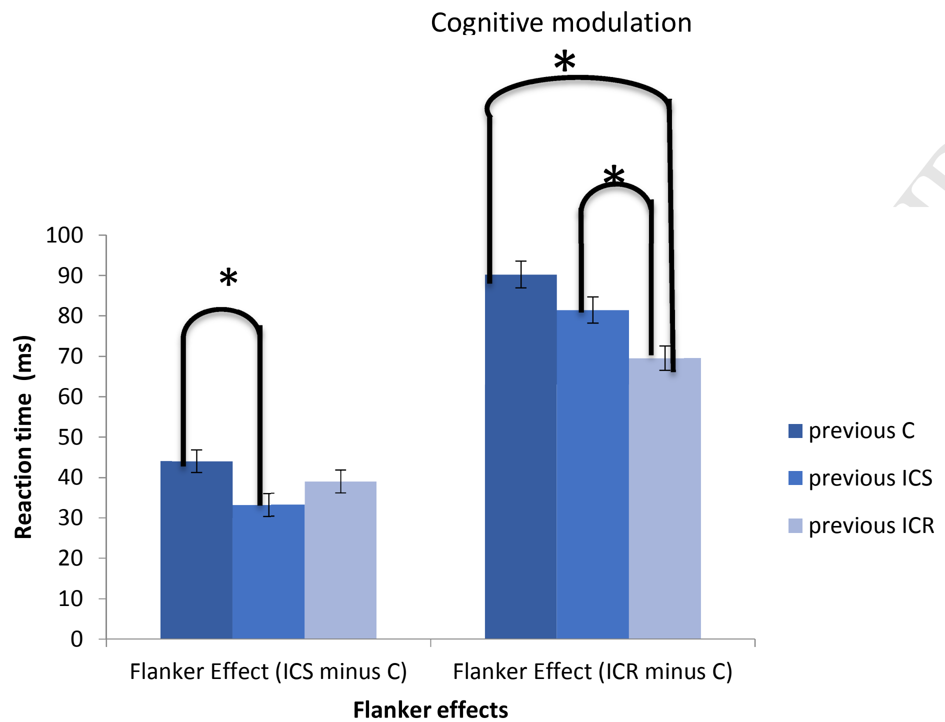

Fig. 4 Illustration of the sequential effects on the flanker effects for both incongruent stimulus (ICS) and incongruent response (ICR) trials showing the differences in flanker effects dependant on previous trial type. * represents statistically significant difference between flanker effect pairings.