Empirical Study: Food-associated response inhibition training to reduce snacking behaviour

Submitted by Jamie O' Sullivan, to the University of Exeter

as a thesis for the degree of Doctor of Clinical Psychology, May 6th 2014

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: ……..

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Authors Declaration Regarding Joint Work

The current study was based on joint work at various phases.

Online Screening and Stimulus Rating

These features were developed by Dr. Natalia Lawrence and Professor Frederick Verbruggen.

Recruitment

Recruitment was shared with another post-doctoral researcher, Dr. David Parslow who collected data for 52 participants and the other 32 collected by trainee clinical psychologist, Jamie O' Sullivan.

Food training task

The food training task was developed by Dr. Mahmood Javaid, Computing Officer, University of Exeter.

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Literature Review: The role of inhibition in overeating

Supervisors

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Abstract

Dietary disinhibition relates to a loss of control over eating and is associated with increased Body Mass Index (BMI) and weight gain. Inhibitory control deficits may lead to elevated BMI by undermining the person's ability to resist the temptations of tasty but unhealthy foods. The purpose of this review was to examine the evidence that links difficulties with inhibition and overeating. Thirteen studies met inclusion criteria and were included in the review. The evidence suggests that disinhibition may be a stronger predictor of BMI than dietary restraint as well as being associated with low dieting success and higher BMI. It also points to developing means of strengthening inhibition control. Various measures exist to objectively measure disinhibition (e.g. stroop task and the go/no-go paradigm). Several laboratory studies and one real-life study have adapted the go/no-go task to 'train' people to be less disinhibited with specific high-calorie foods. Implications of these studies for the development of future food-related inhibition training are highlighted.

Introduction

In developed societies, where palatable, high calorie food is abundantly available, the prevalence of overweight and obese populations has shown an alarming increase over the past 30 years (Flegal, 2005; Wang & Beydoun 2007). The World Health Organisation has declared overweight as one of the top ten risk conditions in the world and one of the top five in developed nations (Hill, Wyatt, Reed, & Peters, 2003). Overeating in a food-rich environment is a key contributor to rising obesity levels (Hill et al., 2003). If overeating plays such an important role in obesity, can this behaviour be reduced effectively?

There is growing evidence that obesity is not only a weight problem but is linked to neurocognitive impairments including reduced cognitive functioning, specifically frontal lobe based executive functions (Gunstad et al., 2007; Cserjesi, Luminet, Poncelet, & Lenard, 2009). Executive functioning is responsible for adjusting human behaviour in a flexible way to situations which require individuals to overcome a strong habitual response or to resist temptation (Norman & Shallice, 2000). Different executive functions may include: cognitive control, the ability to sustain or flexibly redirect attention, the inhibition of inappropriate behavioural responses, initiation and execution of strategies, and the ability to flexibly switch among strategies (Robbins, 1998). People with obesity report that they feel they fail to resist food as a temptation and also report difficulties in controlling aspects of their own lives (Gionta,1995). This reported failure to resist or inhibit ones responses to tempting foods may point to the inhibition aspect of executive function as an area of difficulty in people with obesity. If we can develop a comprehensive understanding of the potential relationship between inhibition and obesity then perhaps we can begin to develop interventions that address this neurocognitive need.

Therefore, the purpose of the current literature review is to examine the evidence-base pertaining to inhibition and overeating using an unbiased and systematic approach.

The search strategy began with a broad aim:

- The role of inhibition in overeating.

This was then expanded into an objective:

- To understand the relationship between inhibition and overeating in people who consume high calorie snack foods.

Finally, the research question was developed:

- Does inhibition play a role in the snack-food consumption of people with obesity?

The search strategy used the research question and research proposal to decide on inclusion and exclusion search criteria. Table 1 shows the first stage criteria for participants.

Table 1.

Participant Criteria

	Inclusion criteria	Exclusion criteria
Participants	Adult* AND (Obes* OR overweight OR overeat*)	(child* OR adolescent* OR animal* OR rat* OR mouse OR mice OR smok* OR depress* OR eating disorder* OR “anorexia” OR “bulimia” OR “binge eating disorder” OR “diabet*” OR "metabol*")

The participants initially included in the search were adults and those suffering from obesity, overweight or overeating. Exclusion criteria included developmental and mental health factors that might confound eating behaviour. However, both criteria were subsequently removed from the search as they yielded very few results in the literature.

Having decided on participants, the intervention criteria were then developed as shown in Table 2.

Table 2

Intervention Criteria

	Inclusion criteria	Exclusion criteria
Interventions	("inhibit*" OR "response inhibition" OR "inhibition control" OR "cognitive control" OR "self control" OR "self-control" OR "executive control" OR "executive function*" OR "self regulation" OR "self-regulation" OR "inhibition training" OR "stop training" OR “behavio?r* therapy” OR “behavio?r* intervention*” OR “impulsiv*”)	("medic*" OR “bio*” OR “pharmaco*” OR “weight watcher*” OR “diet*” OR “exerci?e” OR “physical activity”)

The inclusion criteria focused on variations of ‘inhibition’. Inhibition represents a facet of executive control and can be investigated using various synonyms (e.g. self-control) and antonyms (e.g. impulsivity) in the literature. Exclusion criteria focused primarily on non-psychological interventions as the research is psychological in nature. Other interventions such as dieting or ‘weight-watcher’ programs were excluded as they would confound eating behaviour.

Comparison criteria followed the interventions (Table 3) and focused on other psychological interventions used to investigate eating behaviour.

Table 3

Comparison Criteria

	Inclusion criteria	Exclusion criteria
Comparison	("cognitive intervention*" OR "psychological intervention*" OR "psychological training" OR "cognitive training" OR "psychological technique*" OR "cognitive technique*" OR “cognitive behavio?ral therapy” OR “relaxation therapy” OR “hypnotherapy” OR “placebo group” OR “control group”)	

The inclusion criteria were developed based on mainstream psychological interventions that are available to support people suffering from overweight or obesity. However, these criteria were subsequently removed from the search strategy as they yielded too few results in literature databases.

Outcome criteria (Table 4) were developed following the comparisons. Outcome criteria focus on existing variables in the literature that are indicative of eating behaviour (e.g. caloric intake and weight).

Table 4

Outcome Criteria

	Inclusion criteria	Exclusion criteria
Outcomes	(“weight loss” OR "calor* intake" OR "calor* consumption" OR “calor*” OR "snack intake" OR "snack consumption" OR “snack*” OR "reduc* weight gain" OR "food intake" OR "food consumption" OR “food” OR “energy intake” OR “energy” OR “body weight” OR “weight”)	

Variations and combinations of the words were developed so as to not exclude potentially relevant articles. There was no exclusion criteria developed so as to encourage any indicators of changes in eating behaviour.

Having completed the search strategy, six databases were searched (Figure 1). All searches were confined to research only from 2004 – 2014 in order to identify the most up-to date literature.

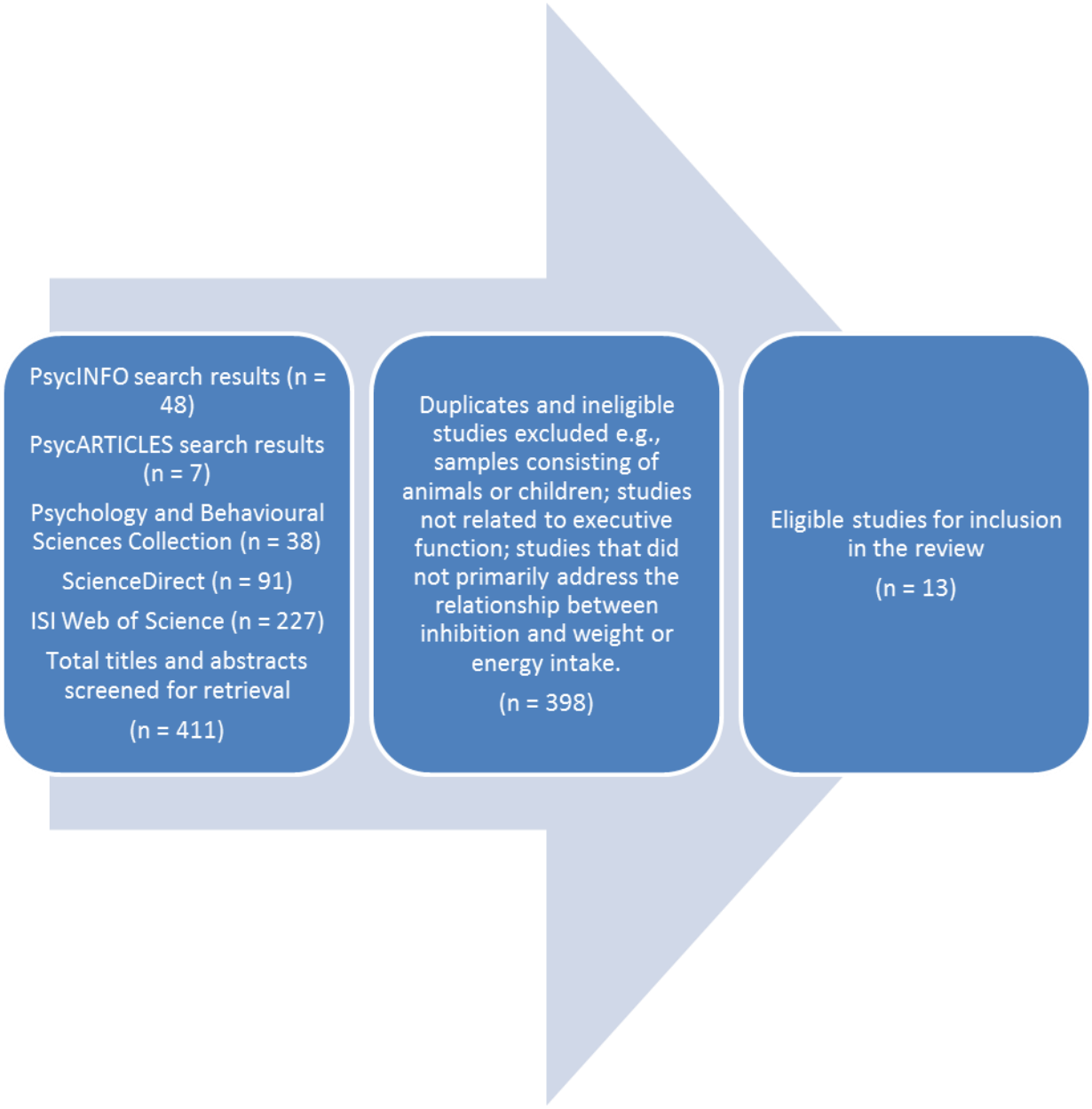

Figure 1. Identification process of included studies

Most searches were conducted on 'all fields' in the search option of the database except where the database permitted more refined searches of the abstract specifically e.g. PsycINFO and Science Direct.

Certain searches were impeded by databases which differ in their search capacities by way of their Boolean operators e.g. Science Direct does not use the exact

same operators as PsycINFO. All these factors may have influenced the literature that each database revealed.

Conceptual and Definitional Problems

Impulsivity. Impulsivity implies low inhibitory control although it is recognized that impulsivity and inhibition are separate constructs. For the purpose of the current review the impulsive process of eating behaviour can be assumed to refer to disinhibition.

Inhibition. The terms behavioral inhibition, response inhibition, self-control and inhibitory control will be used interchangeably to reflect the same construct of executive control (Meule et al., 2014). Executive Control is a general resource in the control of behaviour, emotion and cognition.

Stroop task. Participants name aloud the colour of both incongruently coloured colour words (e.g. the word “red” printed in blue ink) and coloured patches (Stroop, 1935). Large differences in response time between the two conditions are indicative of poor inhibition.

Delay discounting. Refers to the tendency to prefer smaller immediate rewards to larger delayed rewards. Delay discounting has been conceptualised as a result of the competition between an impulsive neurobehavioural system that favours pursuit of immediate rewards, and a reflective executive system that inhibits impulsive behaviour to maximize long-term gains (Bechara, 2005; Bickel, Miller, Yi et al., 2007, as cited in Appelhans, et al., 2011).

Go/no-go task. Measures behavioural inhibition and involves the instruction to respond to a certain stimulus (e.g. by pressing a button), but to inhibit this response to another stimulus.

Stop signal task (SST). A widely used measure of inefficient response inhibition (Barkley, 1997) that uses a choice reaction paradigm in which participants must respond as fast as possible to a visual go-signal, unless an auditory stop signal is presented in which case the response must be inhibited. It is common to generalize the results obtained in the go/no-go paradigm to the stop-signal paradigm, and vice versa.

Implementation Intention. 'If-then' plans, specifying where, when, and how one will achieve their goals e.g. "If I eat out during the day then I will have a vegetarian meal" (Harris et al., 2014).

Theoretical and Research Literature

The results of the following review have been arranged thematically in the following section to reflect the stages that have emerged in the literature with respect to developments in executive control research. Therefore, the initial papers are observational in nature followed by the next stage of experimental studies.

Self-control is an important motivational force that keeps impulsive behaviours in check (Baumeister, 2002). Thus, impulsive unhealthy snacking may occur when self-control is being compromised, for instance when cognitive resources are depleted (Vohs & Heatherton, 2000). Honkanen, Olse, Verplanken and Tuu (2012) used a reflective-impulsive dual-process model to examine the moderating role of food-related self-control in the consumption of unhealthy snack foods. The reflective route was represented by the attitude towards unhealthy snacking, while the impulsive route was represented by the tendency to buy unhealthy snack foods on impulse. Both constructs were measured using three-items on a likert scale in separate self-report questionnaires. Following a web survey on a university student sample, impulsive snack buying tendency showed a positive association with the consumption of sweets but was also moderated by self-control. Thus, when food-related self-control is weak or compromised, the effect of impulsive snack buying tendency on consumption is stronger.

Recognizing the impact of impulsivity on consumption, Epstein, Lin, Carr & Fletcher (2012) examined whether dietary restraint and disinhibition moderate the relationships among the reinforcing value of food, body mass index (BMI), and energy intake in obese as well as non-obese men and women. Restraint and disinhibition were measured using the Three Factor Questionnaire (Stunkard & Messick, 1985). Disinhibition was found to be positively associated with BMI as well as a stronger

predictor of BMI than dietary restraint. Furthermore, disinhibition interacted with food reinforcement to influence energy intake and BMI highlighting the potential importance of inhibition in the development of obesity.

Moving beyond subjective self-report measures, Meule et al. (2014) investigated food-cue affected behavioural inhibition in young women using a go/no-go task with pictures of food and neutral objects. Low dieting success and higher BMI were associated with behavioural disinhibition in food relative to neutral blocks. Thus, unsuccessful control over food intake appears to be related to impaired behavioural inhibition when confronted with palatable food-cues.

Hall (2012) also investigated behavioural inhibition through executive control resources (ECR) to predict resistance to fatty food consumption. ECRs are potentially facilitative of self-control efforts. Two separate tasks measured the behavioural inhibition facet of executive control. These included a go/no-go task and a variation of the stroop task (Miyake et al., 2000). A positive association was found between ECR strength and avoidance of fatty foods over a two-week interval highlighting executive inhibitory abilities as potentially important determinants of dietary behaviour in adults. This also highlights the importance of finding means to augment ECRs e.g. via the use of computer-delivered 'training programmes'.

The stroop task was also used to investigate the role of cognitive inhibition in suppressing eating that conflicts with dietary intentions using a university student sample (Allan, Johnston, & Campbell, 2010). Snacking intentions were measured using two items from a filler questionnaire on consumer behaviour. It was found that the majority of participants failed to behave in line with their dietary intentions and that performance in the inhibitory stroop task explained a significant amount of unique variance in chocolate consumption. Individuals with poor stroop scores ate more

chocolate than those with better stroop scores. Thus, individuals with weak cognitive inhibition who reported intentions to avoid high-calorie snacks ate more chocolate when presented with the opportunity to do so than individuals with comparable intentions but strong inhibition. Stroop performance also correlated significantly with BMI with heavier participants showing weaker inhibition.

Further research linking inhibition and BMI investigated the relationship between BMI and cognitive performance (Gunstad et al., 2007). Tests for executive functioning found that persons with elevated BMI had reduced executive performance, linking obesity with poor cognitive outcome. What's particularly interesting is the use of a modified version of the stroop test which showed the strongest relationship with BMI when compared with the other executive function subtests. These findings strengthen the argument calling for interventions that improve inhibition control so that people may adjust their eating behaviour to be more consistent with their dieting intentions.

Moving beyond the stroop task, Appelhans et al. (2011) tested the interaction between food reward sensitivity and inhibitory control in predicting palatable food intake among energy-replete overweight and obese women. Inhibitory control was measured using a delay discounting task. Delay discounting for monetary rewards was measured using a computerised choice task. It was found that greater food reward sensitivity was associated with increased palatable food intake only among those who demonstrated diminished inhibitory control on the delay discounting task. This evidence lends support for the involvement of inhibitory control of reward-driven eating in weight maintenance.

Jansen, Nederkoorn, van Baak, Keirse and Guerrieri (2009) recognized that the inability to inhibit basic motor responses (e.g. pressing a button) was related to overeating and weight gain. They tested whether this inability to inhibit motor responses using a stop signal task could differentiate between successful and unsuccessful

restrained eaters. It was found that high-restrained eaters only overate if they were also high impulsive. Therefore, it was not eating-restraint alone but coexisting impulsivity that influenced the risk of overeating. This study lends support for research that promotes inhibition or self-control interventions in otherwise impulsive people.

In a similar but longitudinal study, Nederkoorn, Houben, Hofmann & Jansen (2010) investigated weight gain over 1 year in undergraduate female students and found that response inhibition (measured using the SST) interacted with implicit preference for snack foods in their effect on weight change. Participants with less effective response inhibition gained more weight when they also had a strong preference for snack foods highlighting the role of inhibitory control and food-reward value in predicting food intake.

Having recognized the need to promote self-control interventions, Guerrieri, Nederkoorn and Jansen (2012) used the SST to investigate whether training inhibition could lead to less caloric intake during a subsequent taste test. They also sought to induce impulsivity (using the SST) to replicate previous findings that causally linked impulsivity to overeating. It was found that the impulsivity group had a significantly higher intake compared to the neutral group but the caloric intake in the inhibition group did not differ significantly from that in the neutral group. Thus, participants who underwent the manipulation to induce impulsivity showed overeating in the laboratory. However, the clinically relevant option of training inhibition against overeating was not successful. One reason for this finding is that the training of general inhibitory skills might not be strong enough to illicit an effect at the level of eating behaviour. Thus, inhibition training might benefit from a focus specifically on food or even specific types of food before an effect on caloric intake can be expected.

Houben (2011) addressed this issue by examining whether increasing or decreasing inhibitory control respectively decreases or increases food intake relative to a control condition. More specifically, they tested a behavioural training of inhibition using an adapted version of the SST that consistently paired certain stimuli with a certain response. This manipulation was based on a previous study that effectively strengthened participants' ability to inhibit responses to those stimuli that were paired with a stopping response (Verbruggen & Logan, 2008). In the inhibition manipulation, a high calorie food was always paired with a stop signal whereas in the impulsivity manipulation, one type of food was never accompanied by a stop signal. It was found that increasing inhibition toward a food product decreased consumption of that product but only in participants with weak baseline inhibitory control. Conversely, increasing impulsivity toward a food product increased intake of that food product but only in participants with strong inhibitory control at baseline. These findings differed from and built on previous research (Guerrieri, Nederkoorn & Jansen, 2012) by including a control condition and lend support to the view that inhibition can be manipulated depending on the initial level of inhibitory control. In sum, these findings indicate that increasing inhibition is an effective method to decrease consumption of energy-dense food in the laboratory. An important challenge is to develop a way that uses stop signals to improve dieting behaviour in circumstances where stop signals are not physically present i.e. outside the laboratory.

Veling, Aarts and Papies (2011) addressed this issue by examining whether stop signals could be used to control chronic dieters' actual consumption of palatable foods in an everyday life context. Participants completed a task in which a particular palatable food was consistently presented with stop signal or not. Thereafter, they received a candy bag containing that specific food to take home from which consumption was measured one day later. The results revealed that consistently presenting a particular

palatable food near stop signals subsequently reduced chronic dieter's consumption of this food while stop signals did not have this effect among non-dieters. Thus, the stop signal task ensured that chronic dieters acted more in line with their chronic motivation to restrain their food intake across a one-day period. These results are particularly encouraging considering that the intervention task used only lasted a few minutes, and nevertheless affected consumption outside the psychological laboratory. A fundamental question raised by these findings is how consistently inhibiting a response towards palatable food can subsequently improve chronic dieters control of consumption of this food.

Veling, Koningsbruggen, Aarts & Stroebe (2014) recognized this challenge and investigated the effectiveness of two interventions targeting the impulsive processes of eating in affecting people's weight via the internet over a period of four weeks. This included a food go/no-go task and an implementation intention intervention (which reminds people about their dieting goal to promote weight loss). Results indicate that both dieting implementation intentions and the food go/no-go task facilitated weight loss. Additionally, the food go/no-go task facilitated weight loss independent of dieting goal and was primarily effective among dieters with a relatively high BMI. This is the first evidence that a go/no-go task in which foods are consistently presented in close temporal proximity of stop signals can be effective in facilitating weight loss by targeting the impulsive processes of eating behaviour. However, this study is limited by the fact that weight is measured only across a period of four weeks. Hence, conclusions cannot be drawn regarding whether the intervention leads to weight loss over longer periods of time. An area for future study is to test how long effects of one or multiple sessions of the intervention last so that recommendations can be made concerning the frequency of implementing the interventions to reach optimal effects. This is a crucial next step in the research as results of behavioural interventions are generally disappointing as the

majority of obese individuals return to or even exceed their initial weight following treatment (Jeffrey et al., 2000).

Methodological Issues

Various self-report questionnaires (e.g. Impulsive Snack Buying Tendency Scale and Three Factor Eating Questionnaire; Table 5) in the current research provide a quick but subjective measure of inhibition. These have been used frequently in previous correlational studies but are limited by their lack of objectivity and lack of utility in actually bringing about a change in behavioural inhibition.

Table 5

Review Articles Methodology and Measures

Reference	Inhibition/Impulsivity Measures	Key Results
1. Allan, Johnston, & Campbell (2010)	Stroop Task	Only performance on the inhibitory Stroop task explained a significant amount of unique variance in chocolate consumption.
2. Appelhans, Woolf, Pagoto, Schneider, Whited and Liebman (2011)	Delay Discounting Task	Sensitivity to palatable food rewards drives overeating only when accompanied by insufficient inhibitory control.
3. Epstein, Lin, Carr & Fletcher (2012)	Three Factor Eating Questionaire	Dietary disinhibition is positively associated with BMI and food consumption.
4.Guerrieri, Nederkoorn and Jansen (2012)	Stop Signal Task	Impulsivity causes overeating while inhibition training should be focused specifically on food.
5. Gunstad et al. (2007)	Stroop Test	Persons with elevated BMI have reduced executive function performance.
6. Hall (2012)	Stroop Task; Go-NoGo Task	Executive control resources predict fatty food consumption across the adult life span.

7. Houben (2011)	Stop Signal Task	Strenghtening inhibitory control can help people regain control over the consumption of high calorie food.
8.Honkanen, Olse, Verplanken & Tuu (2012)	Impulsive Snack Buying Tendency Scale Food Related Self-control Scale	Attitudes towards unhealthy snacking and impulsive snack buying tendency were positively related to snack consumption.
9.Jansen et al (2009)	Stop Signal Task	Overeating follows from an interaction between restraint and impulsivity.
10. Meule,Lutz, Krawietz, Stutzer, Vogele & Kubler (2014)	Modified Go-NoGo Task; Barratt Impulsiveness Scale-Short Version (BIS-15)	Unsuccessful control over food intake appears to be related to impaired behavioural inhibition when confronted with palatable food-cues.
11. Nederkoorn, Houben, Hofmann & Jansen (2010)	Stop Signal Task	Response inhibition and implicit preference for snack foods interacted in their effect on weight change.
12. Veling, Aarts and Papies (2011)	Go-NoGo Task	No-go cues instantly inhibited responses toward palatable foods especially among chronic dieters.
13. Veling, Koningsbruggen, Aarts Stroebe (2014)	Go-NoGo Task	Food go/no-go task was primarily effective among dieters with a relatively high BMI.

The Stroop task is a long established executive measure of inhibition (Stroop, 1935). It is a useful measure of inhibition as it is sensitive to small differences in executive functioning. However, it is a generic measure of inhibition and has not been modified to be used as an intervention that targets food cues.

Similar to the stroop task, the delay discounting task is a general measure of inhibitory control as it relies on monetary rewards. Tasks assessing discounting of

delayed food rewards have been developed (Estle, Green, Myerson, & Holt, 2007; Odum, Baumann, & Rimington, 2006) but can feature only one class of food reward at a time (e.g. chocolate). Therefore, it cannot measure inhibitory control in the context of all palatable food rewards.

Implementation intentions activate dieting facilitated weight loss through helping participants to think about their plan to diet. It is a well-studied tool to facilitate health behaviour showing that volitional interventions are effective among motivated individuals (Gollwitzer,1999; Sheeran, Milne,Webb, & Gollwitzer, 2005).

It can be seen from Table 5 that two of the most often used tasks for measuring behavioural inhibition are go/no-go tasks and the stop-signal paradigm. In stop-signal tasks, the go signal is presented on every trial, but in a minority of trials a stop-signal is presented shortly after onset of the go signal indicating that one should not press the button on that trial. Stop-signal delay is adjusted dynamically and a stop-signal reaction time is calculated with higher values indicating lower inhibitory performance (Logan et al., 1997). According to Nichols & Waschbusch (2004), the SST is among the tasks with the highest convergent, discriminant and predictive validity. In eating related research the use of the stop-signal task is relatively new, but in attention deficit disorder research the SST is a widely used measure of inefficient response inhibition (Barkley, 1997). As discussed above, these tasks have been modified from their original versions to present stop signals near palatable foods. The fundamental question being asked is whether consistently inhibiting a response towards a palatable food can subsequently improve chronic dieters' control of consumption of this food. While some of the studies previously discussed (Houben, 2011; Guerrieri, Nederkoorn, & Jansen, 2012; Veling, Aarts, Papies, 2011) sought to address this question in the laboratory, only one study to date has conducted this type of training (using the go/no-go paradigm) in the field

and with more than one training session (Veling, Koningsbruggen, Aarts, & Stroebe, 2014).

Conclusion

Summary

The current literature identifies the crucial role that inhibition plays in caloric consumption and potential weight gain. Specifically, low inhibition control could be a risk factor for high caloric intake.

Although, different methodologies exist to measure inhibition, an adapted version of the go/no-go task that pairs stops signals with food cues appears to be the most established method of measuring as well as potentially training response inhibition. The other methods used typically only measure inhibition.

Consideration needs to be given to other factors that moderate caloric intake in addition to inhibition control. These include people with high restraint and high food reward values.

Future research that demonstrates use of the go/no-go paradigm would benefit from training inhibition across several sessions as well as to specific high-reward value foods.

Implications

The use of stop signals paired with food cues to train response inhibition is only in the preliminary stages of development. Future research needs to show long term effects (longer than four weeks) of inhibition training outside of the laboratory. Studies are also needed to investigate the number of response training sessions necessary to show an effect on strengthening inhibition and improving weight loss. Finally, studies conducted outside the laboratory will need to consider the exact process by which the intervention reduces weight. Possibilities include effects on buying behaviour, food choice, portion selection, or amount of consumption.

Appendix I – 'Appetite' Instructions for Authors

APPETITE

AUTHOR INFORMATION PACK

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ISSN: 0195-6663

DESCRIPTION

Appetite is an international research journal specializing in **behavioural nutrition** and the **cultural**, **sensory**, and **physiological influences** on choices and intakes of foods and drinks. It covers normal and **disordered eating** and drinking, **dietary attitudes** and practices and all aspects of the bases of human and animal behaviour toward food.

The journal also carries abstracts from major meetings in the social science, psychology or neuroscience of food consumption, including the Association for the Study of Food in Society, the Society for the Study of Ingestive Behavior, and conferences on Food Choice.

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INTRODUCTION

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Empirical Paper: Food-associated response inhibition training to reduce snacking behaviour

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Abstract

Inhibition is a facet of executive control that can be an area of weakness, in particular in people who overeat. However, laboratory studies suggest that interventions that target disinhibited eating can strengthen response inhibition and ultimately reduce overeating. The current study investigated whether response inhibition could be trained to help reduce food consumption. Eighty four adults who were self-reported disinhibited eaters and predominantly overweight or obese completed five response-inhibition training sessions in a two-week food training study. Participants were randomly allocated to a go/no-go task condition (control versus active) that mapped either non-food stimuli (control) or high-calorie foods (active) on to no-go signals. Participants' weight, calorie intake, daily snacking and food evaluations were measured at baseline and post-intervention. Results indicate that participants in the active condition showed significant weight-loss post-intervention [F (1, 38) = 5.625, p < .023, η_p^2 = .129] as well as a reduction in overall calorie intake [F (1, 39) = 7.951, p < .008, η_p^2 = .169] compared with the control group [F (1, 38) = 0.142, p = .709]. However, there was no change over time [F (1, 79) = 2.280, p = .135] or group differences [F (1, 79) = .144, p = .706] in self-reported daily snacking frequency post–intervention. The active group showed a reduction in ratings of liking of unhealthy (no-go) foods from pre- to post-intervention [t (38) = -1.974, p = .056] compared with the control group [t (40) = 1.040, p = .305]. At one-month follow-up, both groups reported significant weight loss [F (1, 64) = 40.679, p < .001, η_p^2 = .389] as well as a reduction in monthly snacking frequency [F (1, 69) = 14.018, p < .001, η_p^2 = .169]. The results provide supporting evidence that training response inhibition may be an effective technique to help disinhibited eaters become more self-controlled and ultimately reduce their weight.

Introduction

In developed societies, where palatable, high calorie food is abundantly available, the prevalence of overweight and obese populations has shown an alarming increase over the past 30 years, resulting in the majority of adults in the US (c. 70%) now being overweight or obese (Flegal, 2005; Wang & Beydoun 2007). The World Health Organisation has declared overweight as one of the top ten risk conditions in the world and one of the top five in developed nations (Hill, Wyatt, Reed, & Peters, 2003). Overeating in a food-rich environment is a key contributor to rising obesity levels (Hill et al., 2003) begging the question, how can we support people to reduce their over-consumption of food? According to Cavill and Ells (2010), weight management interventions should include behaviour change strategies that improve eating behaviour and reduce energy intake.

Several models of self-control, notably dual process models, indicate that one important determinant of behaviour toward tempting palatable foods is the unintentional elicitation of motor impulses towards these foods when they are encountered (Hofmann, Friese, & Wiers, 2008; Metcalfe & Mischel, 1999; Strack & Deutsch, 2004). Dual-process models suggest that decisions are governed by the strength of two functionally and neuroanatomically distinct but interactive systems: a fast impulsive system, governed by affective reactivity reflecting associations in long-term memory that automatically trigger a motivational orientation (e.g., to approach), and a slower reflective system, associated with conscious deliberation, emotion regulation and governed by cognitive control processes rooted in the prefrontal cortex (Fleming & Bartholow, 2014). Houben and Jansen (2011) suggest that when inhibitory control is lacking, people are more prone to indulge in high calorie food. Thus response inhibition might be required to control eating behaviour in our plentiful food environment.

Response inhibition is a hallmark of executive control and refers to the suppression of actions that are no longer required or that are inappropriate (Verbruggen & Logan, 2008a). It is usually measured in the lab using stop-signal tasks and go/no-go tasks. In both tasks, participants are required to respond to stimuli on go trials but to withhold their response when a stop signal is presented (typically an auditory tone or visual cue). Stop signal tasks impose a delay between the stimulus and a stop signal (so require cancellation of an initiated response) whereas in go/no-go tasks, the stop (no-go) signal is presented at the same time as the stimulus so a response should not be initiated. Van't Riet, Sijtsema, Dagevos and De Bruijn (2011) suggest that interventions targeting habitual behaviour such as eating, should promote the inhibition of the habitual response.

Verbruggen and Logan (2008b) found that response inhibition benefitted from practice with consistent stimulus-stop associations. More specifically, they found that responses were suppressed automatically for stimuli that were consistently associated with stopping. Guerrieri, Nederkoorn, Schrooten, Martijn & Jansen (2009) demonstrated decreased food intake following a computer task that generally primed inhibitory control compared to a task that primed impulsive behaviour. More recently, studies have shown that training no-go responses to specific food stimuli reduces the subsequent consumption of those foods (Houben, 2011; Houben & Jansen (2011); Veling et al., 2011). These effects were particularly pronounced in restrained eaters, who are prone to overeating and frequently attempt to diet with or without success (Lowe, 1993). Thus, inhibitory control training might strengthen dietary control over consumption in those vulnerable to overeating.

In terms of the potential underlying mechanisms, Veling, Aarts, and Papies (2011) found that pairing no-go cues with palatable food pictures inhibited (slowed) motor responses to subsequently-presented action 'probes', suggesting that no-go

training causes motor inhibition to food cues, especially in chronic dieters. This supports findings that automatic forms of inhibition lead to fast suppression of motor activation and reduce the need for effortful top-down control (Chiu, Aron and Verbruggen, 2012).

Several studies also suggest that food no-go training could influence behaviour by changing the reward value of stimuli. Houben and colleagues (Houben, Nederkoorn, Wiers, and Jansen,2011; Houben, Havermans, Nederkoorn, & Jansen, 2012) examined whether training response inhibition by consistently pairing alcohol-related stimuli with a no-go response would decrease alcohol intake in heavy drinking college students. They found that participants showed both reduced alcohol intake and increased negative implicit associations with alcohol-related stimuli following the manipulation. These findings support research showing that behaviour towards stimuli and the valence of these stimuli interact, so that consistent behavioural inhibition toward positive stimuli results in the devaluation of these stimuli as measured by subjective likert scales (Veling, Holland, & van Knippenberg, 2008). Veling, Aarts, & Stroebe (2013) also showed that stop signals are effective in changing food choice behaviour via changes in food evaluation but only when people are hungry. In sum, the repeated pairing of no-go or stop cues with positive stimuli (such as alcohol and palatable food cues) leads to a devaluation of these stimuli as measured by the implicit associations test and by subjective ratings.

The dual systems approach supports the need to strengthen automatic inhibition due to the reliance on automatic behaviour when self-control is low. Dual-process theories of behaviour suggest that the behavioural impact of automatic attitudes and personal standards should depend on available resources: If cognitive capacity is high, personal standards should influence behaviour. If cognitive capacity is low, behaviour

should be influenced by automatic attitudes (Strack & Deutsch, 2004; Hofmann, Friese and Strack, 2009). In summary, if food-related response inhibition training effectively boosts automatic motor inhibition and reduces the reward value associated with food cues, it could help at-risk individuals control their food intake without the need for effortful diets. Increasing self-control and reducing sensitivity to food cues using cognitive training was therefore the principle goal of this research. In contrast to previous lab studies, this project examined the effects of repeated training sessions, delivered via the internet at home or work, on a range of 'real world' dependent variables . Five sessions of food-related (vs. control) response inhibition training were completed in one week and effects on weight loss, calorie intake and daily snacking frequency were measured. We also examined training effects on two variables used in previous laboratory studies – food intake in a bogus taste test (e.g. Houben, 2011) and subjective ratings of food images (Veling et al., 2013). Finally, we investigated the longer-term effects of training by contacting people four-weeks after their final session and asking them to provide their current weight and snacking frequency. We predicted that the active group would show a greater reduction than the control group in weight, snacking frequency, calorie intake and snack-food intake in the taste test. We also anticipated a larger devaluation in subjective ratings of the unhealthy (no-go) foods in the active relative to control group.

Finally, since the current research was conducted, a study has just been published that used a very similar investigation, pairing stop signals with palatable foods, in a dieting sample to facilitate weight loss (Veling, van Koningsbruggen, Aarts, & Stroebe, 2014). Four weekly training sessions delivered via the internet resulted in weight loss in the active group relative to a control group that were trained to inhibit to non-food cues. The sample included predominantly young, healthy, female students, and the effects of no-go training on weight loss were significantly moderated by BMI -

those with a higher BMI benefitted from the intervention. In contrast, our community sample was composed of predominantly middle-aged overweight or obese adults who reported some symptoms of disinhibited (loss of control over) eating. The current study is therefore more relevant in assessing the potential clinical and general public health potential of food no-go training on weight loss and eating behaviour.

Research Question

Does food-associated response inhibition training reduce food intake outside of the laboratory when applied to a community sample of predominantly overweight individuals?

Materials and Methods

Ethical approval was granted by the Psychology Department Board of Ethics at the University of Exeter (Appendix II). All participants gave written informed consent to participate in the research (Appendix III).

Design

A between groups-within subjects design was used in the current study. Participants were randomly allocated to one of two groups, with a between group factor of response inhibition training (active versus control) and a within subjects factor of time (Time 1 versus Time 2). Unless otherwise specified, mixed-effects ANOVAs were conducted on dependent variables using SPSS 21 (IBM Corp, 2012).

Participants

Eligibility criteria. Figure 2 shows that a total of 1397 participants completed the online survey and 217 met initial eligibility criteria which required that participants snacked at least three times a week on any of the four training 'no-go' foods (crisps, chocolate, biscuits and cake). This equated to a mean score of 12 over these four foods on the FFQ. One of our dependent variables was the frequency of intake of snack foods presented in the food training task, so we only invited individuals with this minimal level of snacking to participate.

Eligibility criteria also meant that only participants who reported some disinhibited (loss of control over) eating on the EI were invited to participate. This follows evidence that impulsivity and restraint moderate the effects of no-go training in the lab (Houben, 2011; Houben & Jansen, 2011; Veling et al., 2011). As disinhibition is related to impulsivity, scores on the restraint scale (Wardle & Beales, 1987, 1988), increased BMI and weight gain (Hays et al., 2002), we reasoned that individuals high in disinhibition might show a greater response to food no-go training.

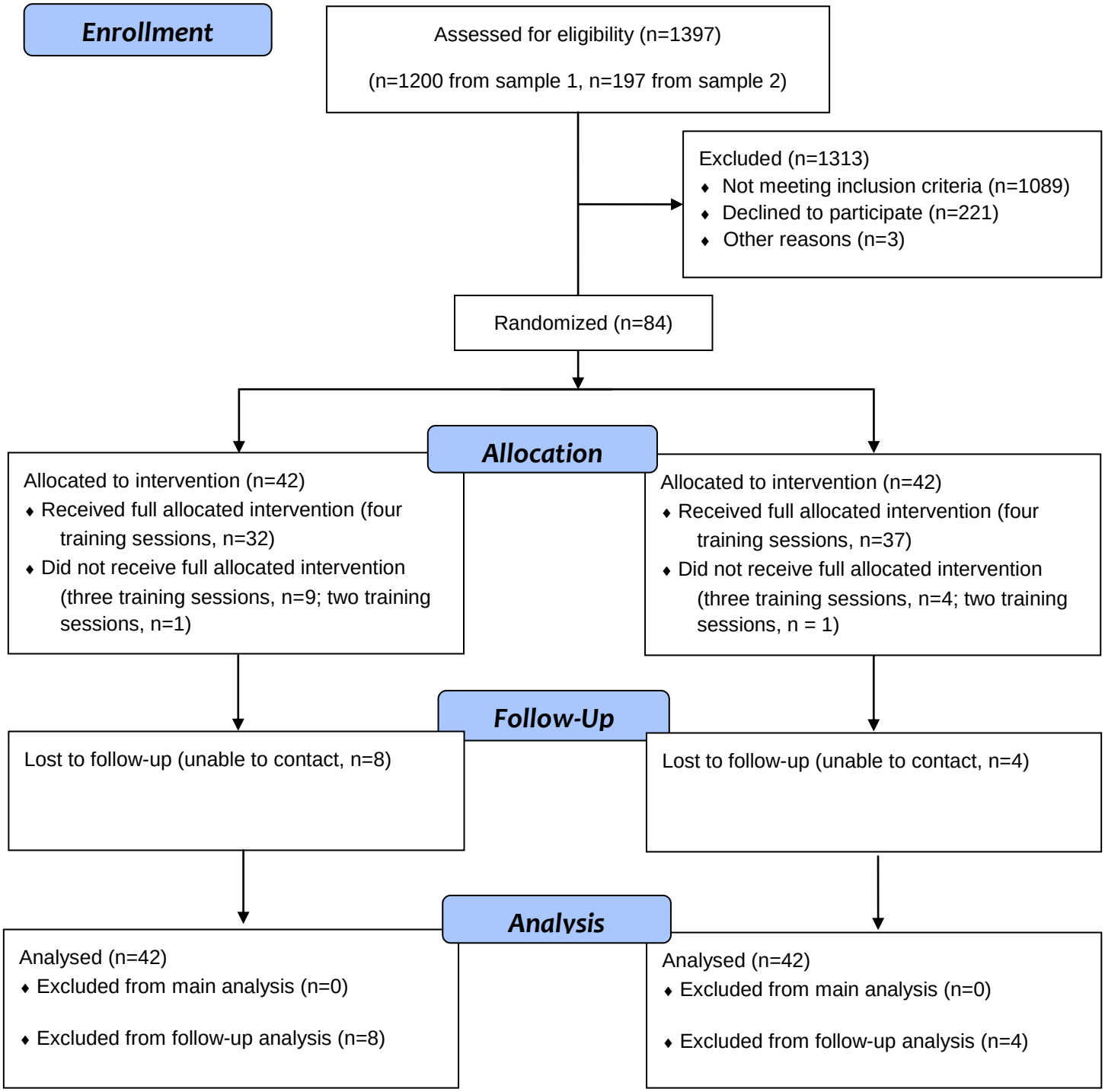

Figure 2. Recruitment flow diagram.

Initially, we only invited individuals with a disinhibition score equal to or greater than the sample median (at least 5 out of 16; Mean = 5.5) but due to time constraints, this was reduced to 3 in the later stages of recruitment. Most of the final sample scored

above 5, however (see Table 6). Elligibility required participants to be aged 18 – 65 to control for developmental confounders (e.g. age-related cognitive decline) and had to self-report a Body Mass Index (BMI) at screening of at least 18.5 (healthy range and above). Suitable participants with a BMI greater than 25 (overweight or obese) were invited to participate first, followed by those with lower BMIs (in the healthy range).

Study exclusion criteria were smoking, recent or present (within the past year) smoking cessation attempts, enrolment in a formal weight-loss programme (e.g. Weightwatchers), use of weight-loss medication, metabolic disorders (e.g. diabetes), allergies to the study foods (chocolate and crisps), and any other health condition that would cause weight-loss (e.g. eating-disorders) unrelated to the intervention. Participants were also excluded if they did not have access to the internet as this was required to deliver the online training.

Sample source. Participants were sourced through the National Health Service from both the Exeter 10000 initiative (sample 1) and a local mental health Foundation Trust staff mailing list (sample 2).

Recruitment strategy. Approximately 11,300 individuals were invited by letter and email (Appendix IV) to complete an online questionnaire about their eating habits, either as part of a study examining the genetics of appetite (1200 participants screened) or to assess their suitability for this cognitive intervention study (197 participants screened; Figure 2).

The online questionnaire consisted of the Disinhibited eating subscale (Appendix V) from the Eating Inventory (EI; Stunkard & Messick, 1985), a Food Frequency Questionnaire (FFQ) that assessed the intake of eight unhealthy snack foods over the previous month (Appendix VI) and three questions related to current dieting (Appendix

VII), along with height and weight to enable estimates of Body Mass Index (BMI; kg/m^2). A total of 84 participants (64 female) were recruited into the study.

Measures

Disinhibition. Disinhibited eating was measured using the sixteen-item 'Disinhibition' subscale from the Eating Inventory (EI; Stunkard & Messick, 1985). The EI shows good reliability and may provide a useful tool for characterizing uncontrolled eating (Cappelleri et al., 2009). Thirteen of the items required a 'True' or 'False' answer (e.g. "I usually eat too much at social occasions, like parties and picnics"). The remaining three items took a rating scale form e.g. "Do you eat sensibly in front of others and splurge alone?" and participants responded on a 4-point scale (1 = never, 4 = always). Disinhibition scores can range from 0 – 16.

Weight. Weight loss at the end of the intervention (after 4 food training sessions) was the primary outcome measure. Participants provided weight in kilograms at screening, baseline, post-intervention (two weeks after baseline reading) and at one month follow-up. Weight was measured by the participants at screening and follow-up, and by the researcher at baseline and post-intervention.

Snacking frequency. Snacking frequency at the end of the intervention was a secondary outcome measure. The Food Frequency Questionnaire (Churchill & Jessop, 2011; Appendix VIII) rates how often eight common snack foods are consumed. The FFQ appears to be reasonably valid in both genders and across different age categories for most food groups with a reliability coefficient of .63 (Willem et al., 2013; Stevens et al., 1996). Snacking frequency assessed at screening was used to inform the unhealthy 'no- go' foods in the training task; in our sample, the most frequently consumed were (in descending order); chocolate, biscuits, cakes and crisps, which were included as no-go foods in the active intervention. At screening and follow-up,

participants were asked to record their snacking frequency over the previous month (e.g. how often they snacked on crisps), and participants responded on an eight-point scale (8 = 4 or more times a day, 1 = less often or never). Scoring was reversed so that a high score meant more snacking. We added an option of "0 = I am allergic to this food so I avoid it" to enable exclusion of participants with relevant food allergies. Participants completed a version of this questionnaire that we modified to measure daily snack food intake (Appendix VIII) for one week at both baseline and during the intervention. A mean total weekly intake of the four 'no-go' foods was computed for each participant for each week.

Caloric intake. Caloric intake at the end of the intervention was a secondary outcome measure. Caloric intake was recorded using self-reported 24-hour food diaries. Participants recorded all food and drink they consumed during two 24-hour periods (one mid-week and one at the weekend) during both the baseline week and post-intervention week (four diaries in total).

Food ratings. A computerised stimulus evaluation test delivered using the researcher's laptop running MATLAB (Mathworks, 2001) measured subjective ratings of food images on a 100 mm visual analogue scale. Separate blocks examined subjective ratings of image attractiveness (Figure 3) and liking of taste (Figure 4)], consistent with previous work investigating stimulus evaluation (e.g. Veling et al, 2008; Veling et al., 2013).

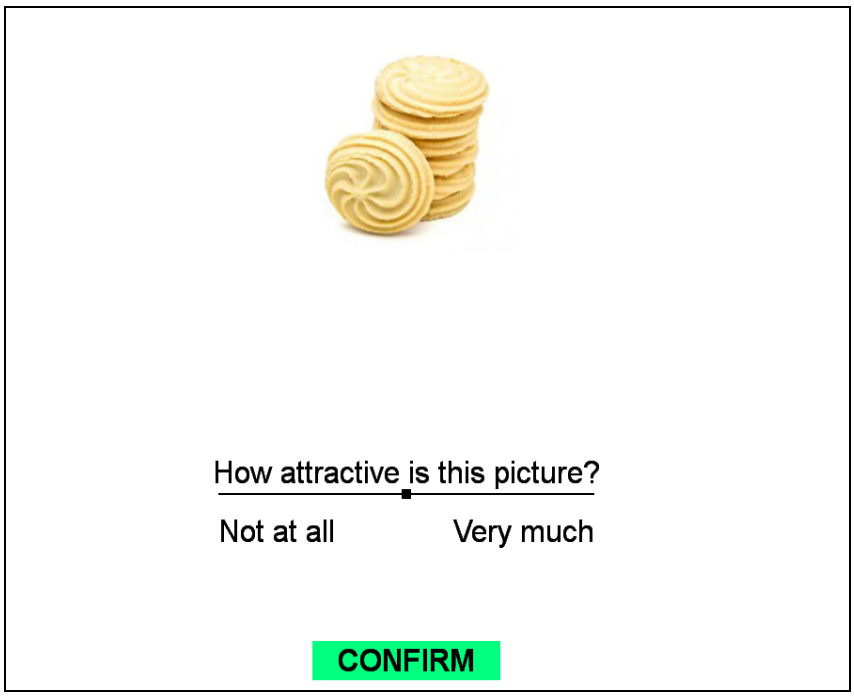

Figure 3. Example of attractiveness ratings stimulus. Participants were required to move the cursor to the appropriate part of the line and then press “confirm” to indicate their rating.

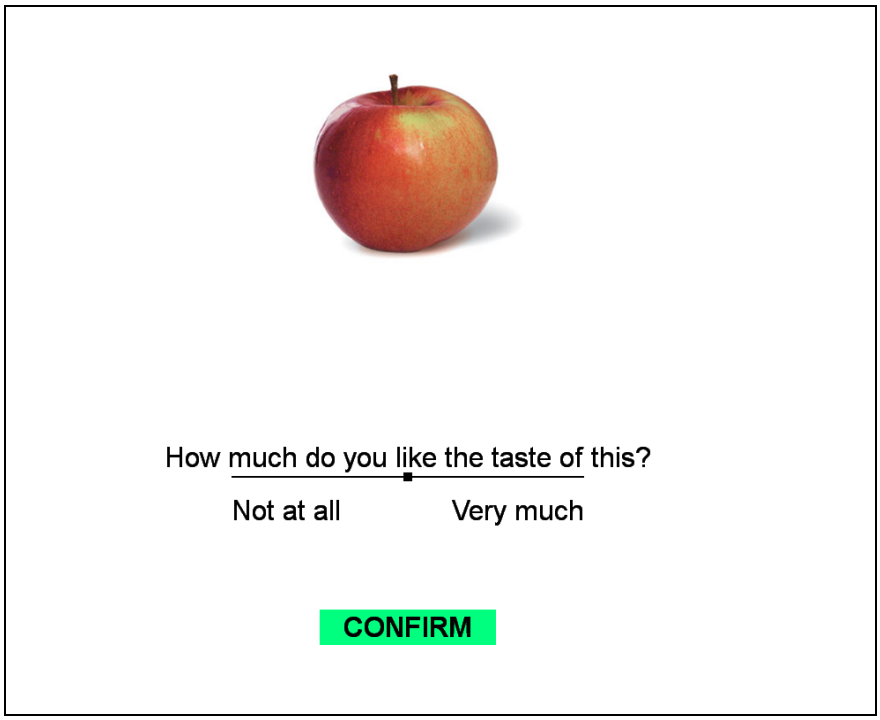

Figure 4. Example of taste ratings stimulus.

This test was administered at baseline and at the beginning of the final session (during the intervention), with the order of the rating blocks (attractiveness or taste first) counterbalanced across participants but kept constant within-subject across sessions. Half of the pictures were taken from the training task and included both the healthy "go" foods (e.g. fruit) and the unhealthy "no-go" foods (e.g. biscuits). The other half of the images were of foods not included in the training task, which were again divided equally between healthy (e.g. dried fruit) and unhealthy (e.g. pancakes) foods. These untrained foods were included to measure the specificity of any change in ratings over time.

Taste test. A bogus taste test was given during the final session to covertly measure the amount of crisps and chocolate (in calories) consumed immediately after the participant's fifth and final training session. This provided a more immediate and objective measure of any training effects on consumption and attempted replication of existing studies where consumption in the laboratory was measured following a single training session (e.g. Houben, 2011).

Training Task

During the online training task, pictures of 18 food (or non-food in the control group) and 18 non-food filler objects were presented individually on the left or right-hand side of a computer screen for 1250 ms (followed by a 1250 ms interstimulus interval). Participants had to press a button ('c' for left and 'm' for right) as quickly as possible to indicate the side of presentation (go-trials; Figure 5). On half of the trials, the frame surrounding the picture was bold (Figure 5), which was a signal for participants to withhold their response (no-go trials). Each of the 36 images was presented once per block and participants completed 6 blocks per training session. They were provided with feedback (accuracy and mean go RT) at the end of each block

to increase motivation, and had to press a key to continue with the task, so they take self-paced rests.

In the active training task images consisted of 18 foods, of which 9 were healthy (fruit, vegetables, rice cakes) and 9 unhealthy (cake, biscuits, chocolate, crisps), along with 18 non-food pictures (clothes). In the control training task images consisted of 18 household objects (furniture, stationery, gardening tools) and the same 18 clothes pictures. Some of the pictures had previously been used in fMRI studies of cue-reactivity, and the food pictures had been rated as pleasant (Beaver et al., 2006; Lawrence et al., 2012). These were supplemented by similar, additional stimuli selected from the internet to ensure sufficient exemplars in each category. Food and non-food images were matched as closely as possible for size, colour and visual complexity. Each picture was presented inside a rectangular frame against a white background (Figure 5).

In the active group, high-calorie food images were always paired with inhibition signals (100% no-go trials) whereas healthy, low-calorie foods were never paired with inhibition signals (100% go trials). The filler images of non-food items (clothes) were equally associated with go and no-go signals, resulting in 50% no-go trials overall.

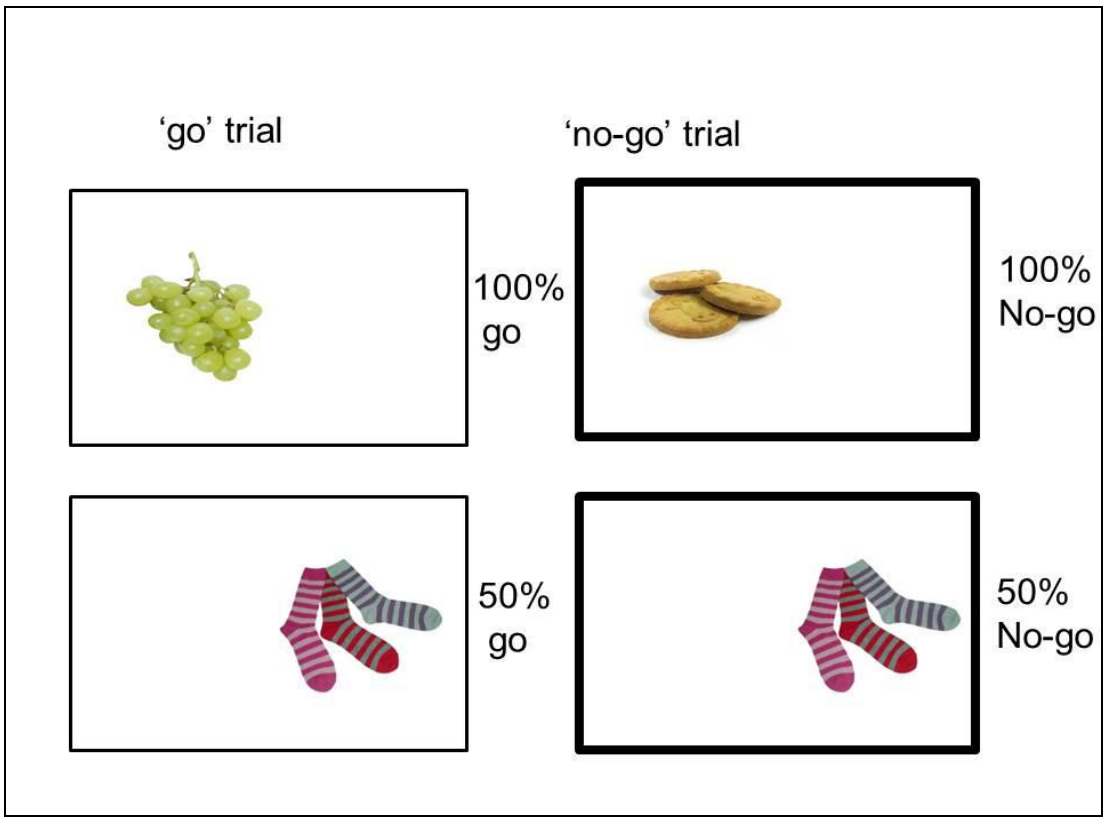

Figure 5. Schematic of the 'go' and 'no-go' trials for the food associated response inhibition task (active condition). Healthy foods were always presented on go trials, unhealthy foods always on no-go trials (bold frame) and filler images of clothes were associated with no-go signals 50% of the time.

In the control group, participants completed an identical task except with pictures of non-food objects replacing the food pictures. The 'go' non-food images included electrical items, furniture and containers (buckets) and the 'no-go' non-food images consisted of DIY tools, gardening tools and stationery. The speed and success of response and the inhibition of responses to foods and non-foods was measured and stored on a secure server.

Procedure

A timeline of the study is shown in Figure 6. Participants were invited for an introductory (baseline) session (15 minutes), where they were briefed about participation in the study. They read a participant information sheet (Appendix IX), were told about the procedure, how to complete the food diaries and FFQ, and gave written informed consent. Participants then performed the baseline computerised stimulus evaluation test, rating the attractiveness and liking of taste of foods. Participants had their weight measured and were given a set of seven daily FFQs and two 24-hour food diaries to complete during the following week (baseline readings; Figure 6).

Figure 6. Overview of food training procedure.

After the first week of recording baseline snack intake and food diaries participants started their online response inhibition training. The first training session took place either in the participant's home or place of work with the researcher present. Participants' identification codes were randomly assigned by the food training programme to either the active (response inhibition) or control condition. Therefore, treatment allocation was set up such that the researcher did not know in advance which group each participant would be assigned to. Although the participants were unaware of their condition allocation, the researcher could see which group they were in based on the nature of the stimuli (high calorie snackfoods) on the participants screen

After completing the training (10 minutes), participants were given another set of seven daily FFQs and two 24-hour food diaries to complete at home during the intervention (training) week.

A second, third and fourth training session was completed over the following three days (intervention week) at the participant's home or workplace. After the second week, all participants completed a final session with the researcher present. They returned their intervention week FFQs and food diaries and performed the same computerised ratings test completed at baseline. They then completed the training task for a final time. Following task completion, they were given a bogus taste test to covertly measure their snack food consumption. Participants were presented with 210g of chocolate buttons and 100g of ready salted crisps in identical large Tupperware containers. They were then required to taste the products and answer questions about each food (e.g. 'How salty is the product?' and 'which ingredients do you taste?'; Appendix X). They were also given four filler questionnaires to ensure that all participants were kept occupied whilst being exposed to the food; the Brief Self Control questionnaire (Tangney, Baumeister & Boone, 2004), the Big Five Inventory (John, Naumann & Sotor, 2008), the Emotion Regulation questionnaire (Gross & John, 2003) and the Mood and Symptoms Questionnaire (Watson & Clark, 1991). Participants were told they could eat as much food as they wanted and were left alone for 15 minutes to complete the taste test and questionnaires.

After 15 minutes, the researcher returned and took the food away. Finally, participants had their weight measured again and were debriefed. The debriefing included a short interview to gauge awareness of the task (stimulus-no-go) associations, aims of the study and feedback about the intervention (see Appendix XI).

Participants were asked to complete a short follow-up questionnaire four weeks after study completion by phone or email, where they provided current weight and monthly FFQ for the past four weeks.

Power Analysis

An a priori power calculation (repeated measures within-between interaction) was conducted using G-power 3.1.5 software. A medium effect size (0.5) would require a sample size of approximately 34 (17 per group) in order to obtain statistical power at the recommended .80 level. A large effect size (0.8) would require a sample size of approximately 16 (8 per group) in order to obtain statistical power at the recommended .80 level (Cohen, 1988). The sample size used in the current study exceeds the minimum numbers required for both effect sizes as well as those used in previous similar studies showing effects of one training session on food intake in the lab (sample size of n = 25 per group; Houben & Jansen, 2011; Houben et al., 2012). We deliberately exceeded the a priori sample size due to the risk of sample attrition.

Results

Sixty-nine of the eighty-four participants recruited completed at least four of the five training sessions (see Figure 2 for further details). As most participants completed four out the five these were included to retain as many participants as possible. They had also completed more than half of the sessions. We also don't know how many sessions are needed to see an effect. If they did three out of four then they did most of intervention. In order to maximize retention we allowed them to drop one session. Therefore, 69 (82%) of those recruited completed most of the training sessions. Randomization checks showed there were no significant differences between training groups for any potential confounding factors (Table 6).

Table 6

Participants Characteristics per Condition

	Control (N = 41)	Active (N = 41)	Range (Minimum – Maximum)	F-value (p)
Age	51.44 (10.17)	49.8 (9.57)	23 – 65	0.56 (.456)
BMI baseline	28.57 (4.78)	29.21 (5.45)	21 – 46	0.069 (.794)
Sex* (% female)	80	78	N/A	0.074 (.785)
Dieting goal* (% of group)	32	27	N/A	0.236 (.627)
Disinhibition	9.56 (3.76)	8.66 (3.35)	3 – 16	1.318 (.254)
Education	15.26 (2.3)	15.08 (2.10)	11 – 19	0.134 (.716)

Note. Standard deviations are presented between parentheses. F and p values refer to one-way ANOVAs except for sex and dieting which are chi square values as they are categorical variables. N/A = Not Applicable.

The final sample included predominantly middle-aged (*M* = 50.62, *SD* = 9.85), overweight (*M* = 28.89, *SD* = 5.1) individuals, 64 of whom were female. The majority of participants were not currently dieting to lose weight and reported moderately high scores on disinhibited eating compared with previous research showing similar mean disinhibition scores in an overweight sample (*M* = 6.2, *SD* = 0.2; Hays et al., 2002) .Twenty-two per cent of participants were a healthy weight (BMI 18.5 - 24.99), 42 per cent were overweight (BMI 25.00-29.99) and 36 per cent obese or morbidly obese (BMI > 30).

Response Inhibition Training Performance

Task performance in all training sessions was checked to confirm high levels of accuracy (at least 80%). This was the case so all participants were retained for analysis. Table 7 displays mean group errors (expressed as a proportion of go and no-go trials) for the first and final training session. It is clear that there were few errors, that performance improved over sessions and that there were no differences between groups. A mixed-effects ANOVA confirmed that go errors improved over time [F (1, 78) = 24.156, $p < .001$] but showed no differences between groups [F (1, 78) = .901, p = .345], or group x time interaction [F (1, 78) < .001, p = .993]. No-go error rates also improved over time [F (1, 78) = 91.249, $p < .001$] but did not differ as a function of group [F (1, 78) = .495, p = .484] or group x session [F (1, 78) = .313, p = .577].

Table 7

Response Inhibition Training Performance

Errors (per session)	Mean	Range
Active group		
Go 1st	.03 (.04)	.18
Go last	.01 (.02)	.12
No-go 1st	.03 (.02)	.09
No-go last	.01 (.01)	.05
Control group		
Go 1st	.03 (.03)	.12
Go last	.01 (.01)	.04
NoGo 1st	.03 (.02)	.10
NoGo last	.01 (.01)	.05

Note. Means represent the proportion of go and no-go trials on which errors were made. Standard deviations are presented between parentheses.

Weight

Weight changes were analysed in two separate ANOVAs comparing baseline versus week 2, and baseline versus 1-month follow-up, due to the methodological differences at follow-up (self-measured instead of researcher-measured weight) and due to the lower number of participants for whom follow-up data were available (weight missing for 14 participants). For weight changes from baseline to the end of week 2, there was no main effect of time [F (1, 77) = 2.287, p = .135] or condition [F (1, 77) = .535, p = .467] but there was a significant time x group interaction [F (1, 77) = 5.798, p <.018, η_p^2 = .070]. As shown in Figure 7, the active group lost a significant amount of weight (on

average 0.66kg) over 2 weeks [F (1, 38) = 5.625, p < .023, η_p^2 = .129] whereas weight in the control group remained about the same [F (1, 39) = .616, p = .437].

Figure 7 also shows substantial reductions in weight in both groups at follow-up; this was confirmed by a main effect of time [F (1, 64) = 40.679, p < .001, η_p^2 = .389] but no significant differences between groups [F (1, 64) = .382, p = .538] or group x time interactions, [F (1, 64) = .684, p = .411]. See supplementary table (Appendix XII) for further specification of these and other outcome variables.

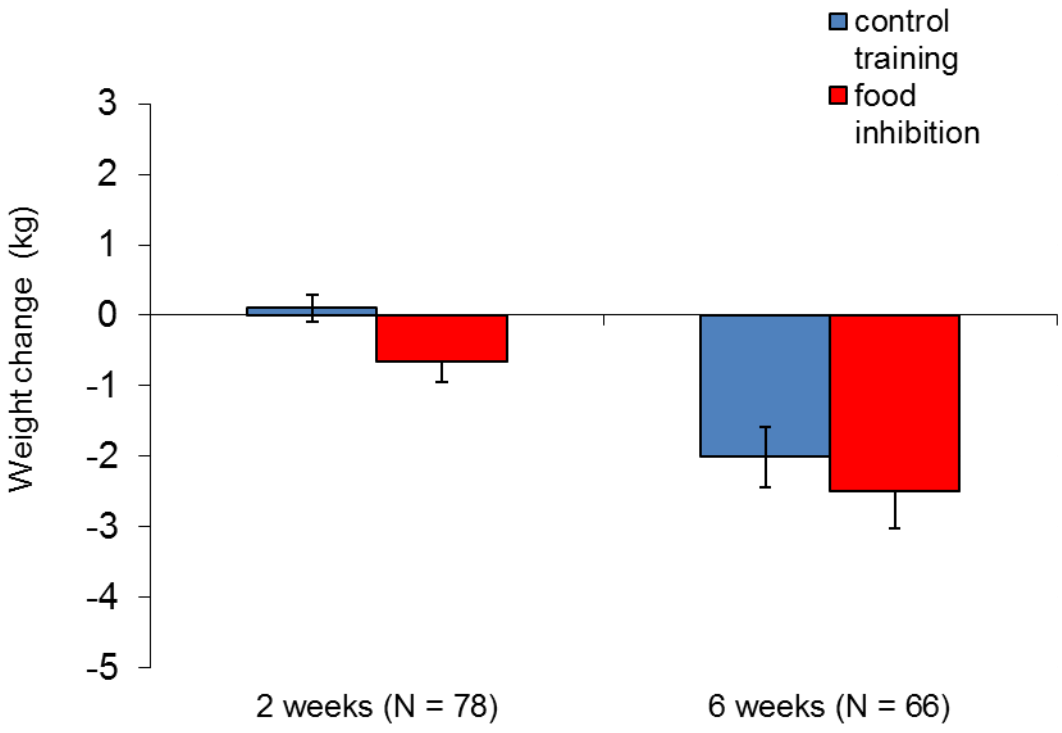

Figure 7. Weight change over time as a function of inhibition training condition; a negative change indicates weight loss from baseline to post-intervention. Error bars = Standard Error of the mean.

Snacking Frequency

The change in snacking frequency, summed over the four “no-go” foods, was analysed in separate ANOVAs for baseline versus week 2, and screening versus 1-month follow-up. Separate analyses were conducted because of the smaller sample at follow-up, but also because the measures were different; daily snacking frequency was summed to give a mean weekly total for the baseline and intervention week (week 2), whereas one FFQ measuring snacking frequency over the previous month was used at screening and at one-month follow-up.

Figure 8 suggests a reduction in snacking from baseline to week 2 but this effect of time was not significant [F (1, 79) = 2.280, p = .135]. There were also no significant differences between groups [F (1, 79) = .144, p = .706] or group x time interactions, F (1, 79) = .950, p = .333.

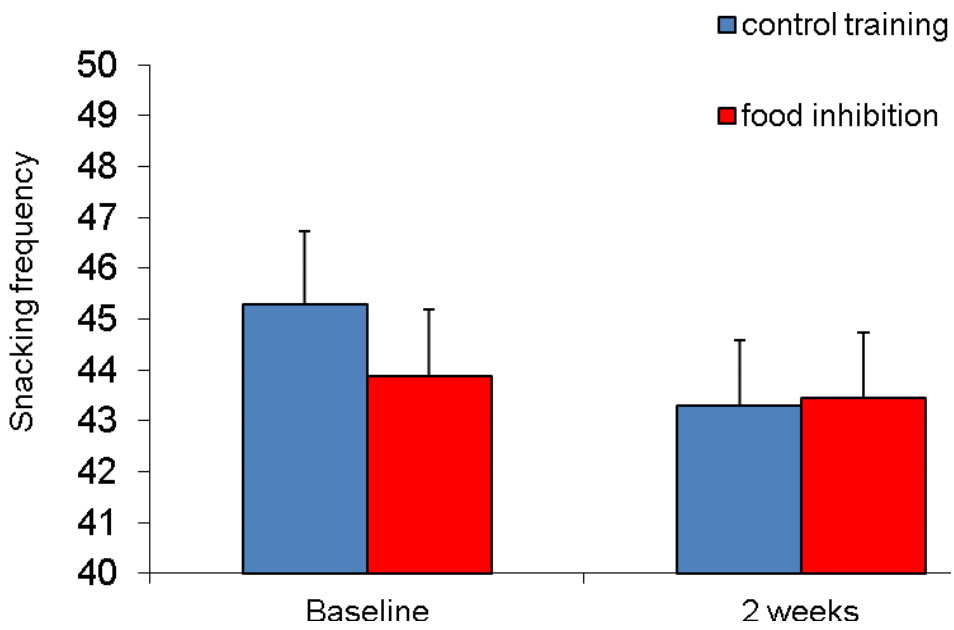

Figure 8. Snacking frequency (weekly total) at pre- and post-intervention as a function of inhibition training condition; Error bars = Standard Error.

At one month follow-up (Figure 9) there was a significant decrease in monthly snacking frequency relative to screening [$F(1,69) = 14.018$, $p < .001$, $\eta_p^2 = .169$]. However, there was no main effect of condition [$F(1,69) = .207$, $p = .651$] nor time x condition interaction, [$F(1,69) = .211$, $p = .648$]. Figure 9 shows that both groups showed a reduction in monthly FFQ scores from around 15 at screening to around 13.5 at follow-up. This would be roughly equivalent to reducing intake of the four snack foods from 2-4 times per week at screening to once per week at follow-up.

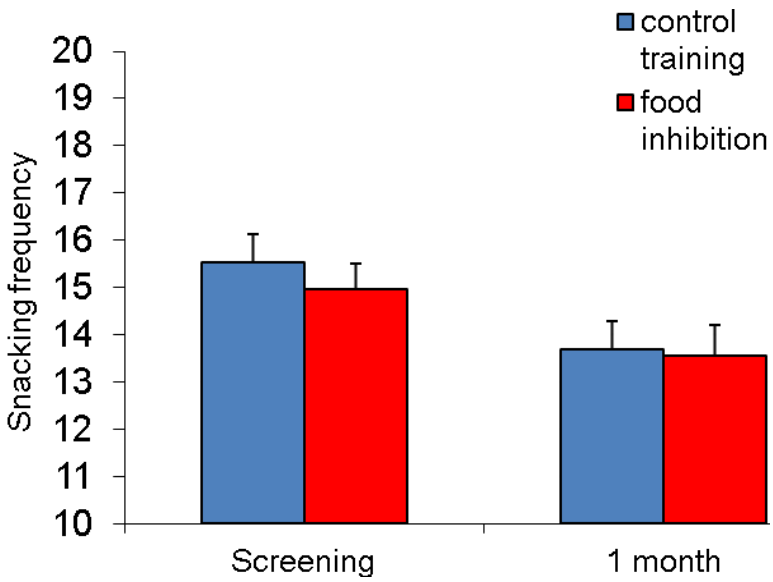

Figure 9. Monthly snacking frequency over time as a function of inhibition training condition; Error bars = Standard Error.

Caloric Intake

The change in estimated daily caloric intake (averaged over two 24-hour food diaries) was only available for baseline versus week 2. Food diaries were not collected at follow-up due to the time demand on participants.

Figure 10 shows that there was a reduction in calorie intake in the active group from baseline to week 2. This was supported by a significant time x group interaction [*F*

(1, 77) = 5.565, $p < .021$, $\eta_p^2 = .067$], with no significant effect of group [F (1, 77) = 1.620, $p = .439$] or time [F (1, 77) = 3.467, $p = .066$]. Follow-up tests indicated a significant drop in calorie intake in the active group over time [F (1, 39) = 7.951, $p < .008$, $\eta_p^2 = .169$], but not in the control group [F (1, 38) = .142, $p = .709$].

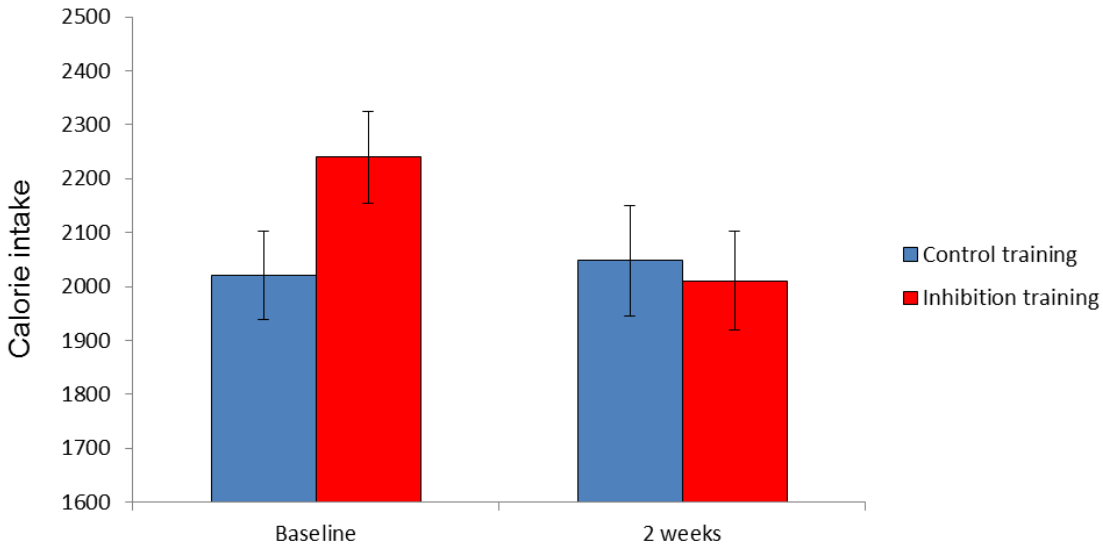

Figure 10. Change in daily calorie intake estimated from food diaries over time as a function of inhibition training condition; Error bars = Standard Error.

Evaluation of Food Images (Taste/Liking and Attractiveness Ratings)

There were a large number of outcome variables in the stimulus evaluation test due to the use of two different ratings scales, 4 different categories of food images (healthy and unhealthy foods that did and did not appear in the training task) and 2 time points (baseline and end of week 2). To simplify this analysis and reduce data, we calculated change scores for ratings of liking and attractiveness (separately) for each category of food images. These change scores were computed for each participant by subtracting ratings at baseline from ratings at time 2, so that a negative score reflects a drop in ratings over time, consistent with devaluation.

Figure 11 shows that, in general, ratings of liking decreased from baseline to week 2. We ran a mixed-effects ANOVA with group (training condition) as a between-subjects factor and food category (4 levels; healthy-trained, unhealthy-trained, healthy-untrained and unhealthy-untrained) as repeated measures. There were no main effects of group [F (1, 78) = 1.961, p = .168], food category [F (3, 76) = .031, p = .993] or group x category interaction [F (3, 76) = 1.409, p = .241].

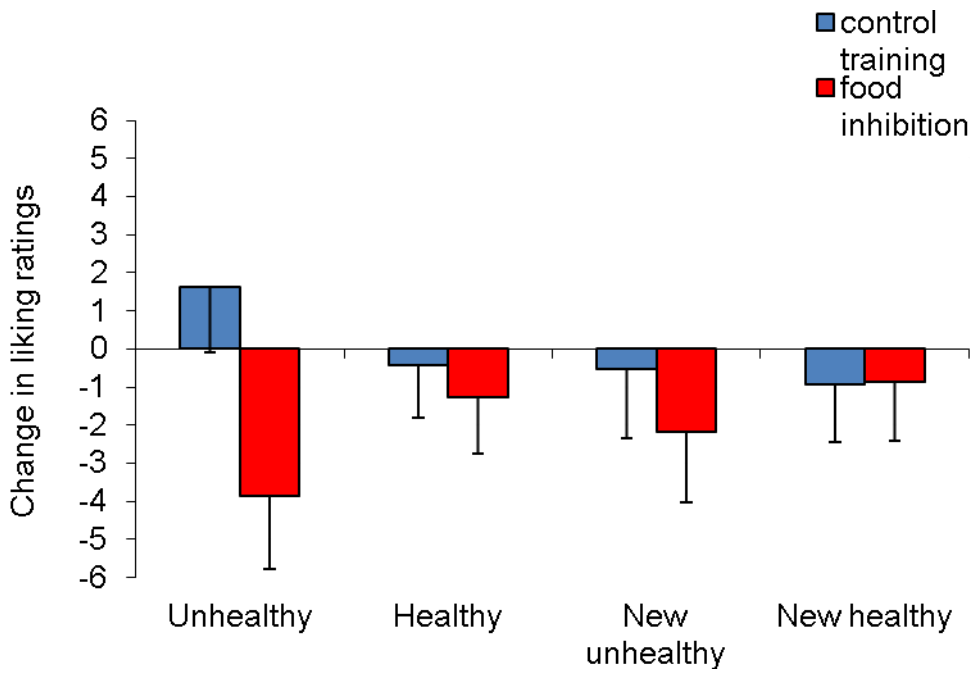

Figure 11. Change in liking ratings from baseline to week 2 as a function of inhibition training condition; Error bars = Standard Error.

Whilst there was no group x food category interaction in the overall ANOVA reported above, based on existing studies we had specifically predicted a reduction in ratings for the unhealthy foods paired with no-go signals in the active, relative to the control training condition (Houben et al., 2012; Veling et al., 2013). Therefore we also conducted a planned between-group ANOVA on the change in liking ratings for the unhealthy (no-go) foods only, which suggested a significant difference between groups [F (1, 79) = 4.714, p = .033]. As shown in Figure 11, liking ratings for unhealthy (no-go)

foods decreased over time in the active training group [t (38) = -1.974, p = .056] and increased slightly (but not reliably) over time in the control group, [t (40) = 1.040, p = .305].

For changes in ratings of attractiveness, the pattern of results looked rather different. Figure 12 shows that, in general, ratings of image attractiveness increased from baseline to week 2, with the exception of unhealthy (no-go) foods, which showed a reduction. A mixed-effects ANOVA on attractiveness change scores indicated a main effect of food category [F (3, 75) = 3.002, p = .036, = η_p^2 = .107], but no effect of group [F (1, 77) = .507, p = .478] or group x category interaction [F (3, 75) = .375, p = .771]. Follow-up paired t-tests between the pairs of food categories showed that only unhealthy and healthy (trained) foods differed significantly for change in attractiveness ratings, with this being significantly more negative for unhealthy than healthy foods [t (78) = -3.072, p = .003]).

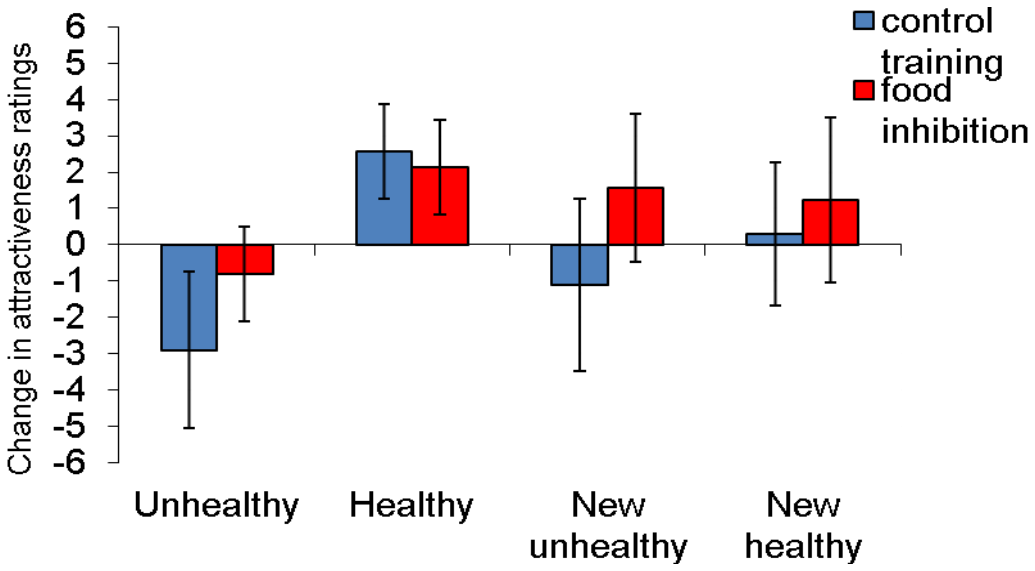

Figure 12. Change in attractiveness ratings from baseline to week 2 as a function of inhibition training condition; a negative change indicates a drop in ratings over time. Error bars = Standard Error.

Taste Test

A t-test showed that both groups consumed similar amounts of snack foods (chocolate and crisps) in the bogus taste test after the final online training session. The active training group consumed a mean total kcal of 181.3 ± 196 (SD) kcal, and the control training group consumed a mean of 152.3 ± 124 (SD) kcal, [t (80) = 0.801, p = .425].

Post-hoc Correlations between Significant Dependent Variables

Correlations were conducted to examine whether weight loss at the end of training and at one month follow-up were related to changes in other variables showing intervention effects (snacking frequency at follow-up, calorie intake, change in unhealthy food ratings). In the whole sample, a correlation was observed between weight loss at 2 weeks and after 1 month [r (65) = .399, p = .001], indicating that early

changes in weight were predictive of later changes. There was also an association between weight loss at 1-month follow-up and the drop in snacking frequency from screening to 1-month follow-up [r (60) = .294, p = .023]. There were no other significant correlations. In the active training group, there was a trend towards a correlation between weight loss at 2 weeks and reduction in liking of unhealthy food at 2 weeks [*r* (37) = .297, *p* = .075].

Factors Moderating Training Effects

Finally, we completed two moderated regression analyses to see whether the effects of active vs. control training were moderated by factors previously shown to moderate food no-go training effects; BMI (Veling et al., 2014) and food-related self-control (Houben & Jansen 2011; Veling et al., 2011). Potential moderators in our study were participants' BMI at baseline and disinhibition scores. The modprobe SPSS macro (Hayes & Matthes, 2009), which explores interactions in multiple regressions, was used with training condition (dummy-coded) as the focal predictor variable, weight change as the dependent variable and BMI (or disinhibition) as the moderator variable. Results indicated no interactions between training and BMI for the weight change at 2 weeks (*t* = -.362, *p* = 0.718; ΔR^2 = 0.0017) or 1 month (*t* = .694, *p* = .490; ΔR^2 = .0078).There was also no interaction between training and disinhibition scores for weight change at 2 weeks (*t* = 1.588, *p* = 0.117; ΔR^2 = 0.03), or 1 month (*t* = 1.167, *p* = .248; ΔR^2 = .022).

Discussion

The current study was a preliminary investigation into the effectiveness of computerised response inhibition training to foods on consumption and weight loss. Participants completed a total of four or five go/no-go training sessions in either an active (food-associated response inhibition) or control (non-food-associated response inhibition) condition. Participants in the active condition showed significant weight-loss post-intervention as well as a reduction in overall calorie intake compared with the control group.

Weight loss from baseline to post-intervention (week 2) suggests that the training task was effective in helping participants to lose weight in the active condition but not in the control condition. This finding complements recent research (published after this study was conducted) showing that a food no-go training can be effective in facilitating weight loss (Veling, van Koningsbruggen, Aarts, & Stroebe, 2014). Veling and colleagues showed an approximate weight loss of .55kg (η_p^2 = .15) for participants in the food no-go task over a 4 week period (which increased to approximate 1.5 kg in their high BMI participants), which is below our weight loss of .66kg (η_p^2 = .129) at 2 weeks and 2.5 kg at 1 month follow-up. Both studies demonstrated a large effect size on weight loss; the greater reduction in our study may be linked to the increased weight of our participants at baseline. Interestingly, Veling et al. (2014) also showed a further .35kg loss for those exposed to a combined food no-go task and dieting implementation intervention. These findings build on previous laboratory research showing that the food-related no-go training is effective in helping people reduce intake of high calorie foods (Houben & Jansen, 2011; Veling, Aarts, & Papies, 2011).

Weight loss at 1-month follow-up was significant in both training groups. Whilst the sustained weight loss in the active group suggests that training may still be effective

after 1 month, the weight loss in the control group was unexpected and points to non-specific intervention effects. These non-specific effects could have included the following: i) The monitoring nature of the study (using food frequency questionnaires and food diaries over two weeks) could have made participants more aware and mindful of their eating behaviour and reduced intake in both groups; ii) there may have been some beneficial effects of general response inhibition training on eating behaviour; iii) participants may have been reporting reduced weight due to study demand characteristics. Whilst the cause of weight loss in both groups at 1-month follow-up is unclear, the association with reduced monthly snacking at follow-up suggests it could be related to delayed changes in eating behaviour. This is the first insight into follow-up weight readings following response inhibition training and future studies with more control groups (involving food /snacking diaries but no response inhibition training) are required to understand this general weight loss more clearly.

Ratings on the food frequency questionnaires did not differ across conditions between baseline and week 2 although there was a trend towards reduced snacking. Although this measure did not show any change between groups, the active group lost weight at the end of week 2 suggesting a potential change in calorie intake or other behaviour such as exercise. Results from the analysis of the 24-hour food diaries are consistent with this - the active group showed a significant reduction in calorie intake over 2 weeks compared to the control group. This is the first time this type of training has been conducted with food diaries and indicates that they may be a more representative outcome measure compared with the FFQ, as the FFQ may not be capturing the full picture with regard to food consumption. The FFQ lists specific high calorie foods only; it is possible that participants are consuming less of other type(s) of high calorie food. The FFQ is also an imperfect measure of snacking as it negates portion size and is therefore at risk of overestimating or underestimating snacking

frequency compared to other food records (see Paalanen et al., 2006 for discussion of this topic). Interestingly, there was a significant effect of time on monthly snacking frequency at follow-up relative to screening but for both groups. Possible explanations for these non-specific training effects on snacking are discussed above for weight loss at follow-up. Unfortunately, calorie consumption was not measured at follow-up so we cannot determine whether there were also non-specific delayed effects on this measure, but future research could examine this.

In terms of possible mechanisms underlying the food no-go training effects, findings from the stimulus evaluation test offer some support for stimulus devaluation. Our data indicate both specific effects of active training in reducing liking of “no-go” foods, but also some general intervention effects (in both groups) on reducing attractiveness ratings. The drop in liking ratings for unhealthy no-go foods in the active group compared to the control group (who were not trained to inhibit to these foods) is consistent with previous similar findings that stop signals change food choice behaviour through reductions in food evaluation (Veling, Aarts, & Stroebe, 2013). It also complements research showing that behavior towards stimuli and the valence of these stimuli interact, so that consistently not responding to positive stimuli results in their devaluation (Veling, Holland, & van Knippenberg, 2008; Houben et al., 2012). In sum, findings from the liking ratings support stimulus devaluation as a likely mechanism of food no-go training. Future research could examine longer term devaluation effects.

The attractiveness ratings showed a change over time for both unhealthy and healthy foods. Specifically, unhealthy food images were rated as less attractive in both groups while the healthy food images increased in attractiveness in both groups. While we might expect these changes in the active group it is unclear why the control group showed a similar trend. This might reflect a general effect of response inhibition training

and maintaining food records, as both groups also ate less of these unhealthy foods at follow-up. The different results observed for liking and attractiveness could be linked to, respectively, a greater sensitivity to detect personal hedonic reactions and motivation to engage with the foods (liking of taste) as opposed to general affective responses (attractiveness of image).

Surprisingly, we did not see any difference between groups in calorie consumptions in the taste test. Previous response inhibition training has shown a reduction in the consumption of foods presented on no-go trials in a subsequent bogus taste test (Houben, 2011; Houben & Jansen, 2011, Guerrieri, Nederkoorn, & Jansen, 2012). However, these previous studies were conducted under controlled laboratory conditions (e.g. participants were asked not to eat for 2 hours and were seen at specific times of day) unlike in the current study which was conducted in a real-life, uncontrolled context. In addition, lab studies have used control conditions matched for food cue exposure – so participants had to go in response to unhealthy foods. This may have increased approach motivation towards foods (Schonberg et al., 2014) or primed disinhibition (Guerrieri et al., 2012) and therefore increased the subsequent intake of food in controls in these taste tests, confounding the interpretation of results. Future lab studies comparing food no-go and non-food no-go training on intake in a taste test would help to resolve these issues.

Interestingly, BMI and disinhibition did not moderate training effects on weight changes from baseline to week 2. This is inconsistent with previous research indicating a moderating effect of BMI on weight change (Veling et al., 2014). However, the current sample were older and more overweight than the sample in Veling et al. (2014) and were in fact similar to their high BMI group, which did show training effects. Thus, perhaps there is no further moderation of training by BMI once people are overweight.

The same may apply to disinhibition – the lack of moderation effects could be linked to the generally moderate-high levels of disinhibition in our sample.

The lack of significant correlation between change in calorie intake and weight loss over 2 weeks raises questions about the mechanism underlying the effect of the food no-go training. Perhaps there are other mechanisms involved (such as devaluation, discussed above), or others (such as exercise) that we are unaware of and did not measure, or perhaps the 24-hour food diaries are not a sensitive measure (Pears et al., 2012).

The current study investigated whether food-related response inhibition training is effective in reducing food-intake. The preliminary evidence suggests that food response inhibition training is showing an effect on food consumption as evidenced by weight and calorie reductions over two weeks and some devaluation of unhealthy foods. However, snacking frequency and taste test outcomes are inconclusive. The outcome of the inhibition training also lends support to the previously mentioned dual process model of self-control. Specifically, participants who cannot always rely on their reflective system (based on personal standards) to guide appropriate behaviour may benefit from training that develops new, automatic and more helpful associations within their impulsive system that ultimately results in healthier food choices.

Limitations

The current study had several limitations. First, participants' increased self-monitoring (through the use of food diaries and food frequency questionnaires) may have influenced their eating behaviour during the study, thereby compounding the influence of the food training task. Second, the current study did not control for measures of appetite in the taste test, which has significant effects in lab studies of food no-go training (Veling, Aarts, & Stroebe, 2013). Third, some participants gave

ample detail in the food diaries while others provided sparse detail. This meant that the calorie readings for some diaries were better estimations than for others. Fourth, it would have been helpful to have measured self-reported disinhibition scores at the end of week 2 and at follow-up to evaluate perceived changes in control over eating behaviour as a potential mechanism. The current study relied on measures of weight and caloric intake to indirectly measure this indication of change. Fifth, previous research has shown the moderating effect of dietary restraint on inhibition such that inhibition training proved especially effective for restrained eaters and chronic dieters (Houben & Jansen, 2011; Veling et al., Veling et al., 2011). Although the current study did include some participants who were dieting, this was less than 32 per cent in each condition and additionally this could have been screened using a more sophisticated method such as the dietary restraint scale (Herman & Polivy,1980) as used in recent food inhibition studies (e.g. Veling, Aarts & Stroebe, 2013). However, the current study examined moderations by disinhibition instead of restraint because recent studies suggest that training effects are stronger in more impulsive eaters (Houben, 2011; Veling et al., 2014) and scores on the restraint scale are associated with disinhibition (Johnson, Pratt & Wardle, 2012). Lastly, the one-month follow-up data was collected after participants had been debriefed. This meant that there was potential for bias in these self-report measures. Therefore, interpretations based on follow-up data may not be as robust as those made from more objective outcome measures such as weight (measured by the experimenter).

Clinical Applications and Implications for Future Studies

Further procedures that aim to strengthen inhibitory control may prove to be a useful strategy not only for the prevention of overweight but also for clinical treatment of obesity. Often, behavioural interventions are disappointing because the majority of obese individuals return to or even exceed their initial weight following treatment (Jefffrey et al. 2000, as cited in Houben, 2011). Increasing inhibitory control abilities may supplement existing behavioural interventions for obesity e.g. Cognitive behavioural therapy by targeting more automatic processes (Marteau, Hollands, & Fletcher, 2012). This training may also be extended to other clinical populations (e.g. people with cognitive impairment due to dementia, brain injury or learning disabilities) who might have reduced response inhibition (affecting their eating behaviour). This might be attractive to clinical psychology services in particular because it would be relatively inexpensive to administer and doesn't rely on a high intellectual ability to complete the task, thereby encompassing a wide clinical population.

The current study used five food training sessions. Future work could investigate whether further training sessions can lead to even more long-term associations between inhibition and high calorie foods post intervention and at longer follow-up intervals (e.g. at six months). Future studies might also consider the use of weekly, monthly or 'on-demand' 'top-up' training sessions to strengthen response inhibition and reduce high-calorie food intake. It would be interesting to see if this has an effect as previous work in the lab indicates that the devaluation effect of foods associated with no-go cues can be achieved in as few as four food-no-go pairings and is not augmented by further associations (Veling et al., 2013). As the current study was a preliminary trial, future research might also benefit from a larger randomized controlled trial with a greater number of potential moderator and mediator variables being

measured. A sample that is overweight and disinhibited seems to be effective for the existing study and therefore could be used in future trials. As this is the first study of its kind to use a modified version of the FFQ it will be helpful for future research to identify a validated tool that might be more sensitive to changes in eating behaviour. Future studies might also include extra control groups such as no-intervention (‘wait-list’) controls and a diary-only control group to better isolate the effects of inhibition training on eating behaviour and weight loss. Studies might also benefit from customizing training to the specific high-calorie foods that individuals struggle to resist in order to maximize the effect of stimulus-specific response inhibition training. Lastly, for future research, it doesn't seem to matter whether people are aware of the associations in the task or not as both those who were and weren't (in the active group), lost weight (see supplementary table for further details; Appendix XII).

Appendix II – Ethical Approval

Psychology online Ethics system - Jamie O'Sullivan

This Application has been marked as accepted, so no further edits can be made.

Project details

Conditions of acceptance

This application is approved with the following conditions:

- The debrief information sheet must contain a description of and explanation for the deception (the filler test items).
- You indicate that you would be happy to provide further information to participants once data analysis is completed, but do not indicate mechanism whereby this can be made possible. Please resolve and clarify the mechanism.
- Debrief information sheet section, 'Who has reviewed this study?' is incomplete - please amend as appropriate.

Please email a single document addressing these issues to the Chair, Psychology REC (C.N.W.Burgess@ex.ac.uk), along with your applic reference number, for Chair's Action.

® Title of Project (max 25 words)	Training Response Inhibition to Reduce Snacking Behaviour
® Type of Project	Study not requiring approval by NHS NRES
® Names of researchers	Dr. Natalia Lawrence Dr. Frederick Verbruggen
® Correspondent's Email (separate with a semi-colon if providing more than one)	Natalia.Lawrence@exeter.ac.uk;F.L.J.Verbruggen@exeter.ac.uk
Estimated start date (dd/mm/yyyy) and duration of the project	01/05/13 - 12 months

Research Groups		
	Animal Behaviour	☐
	Clinical	☐
	Cognition	☑
	SEORG	☐

Project Supervisor

® Please select

Natalia Lawrence

Appendix III – Consent Form

If you wish to participate in this study you will need to meet the inclusion criteria below and be willing to agree to the following consent statements.

CONSENT STATEMENTS

1. I confirm that I have read this leaflet and have had the opportunity to ask questions and have had these answered satisfactorily.
2. I am happy to participate in this study by completing computer - based tasks and food diaries.
3. I understand that I may be given either a "control" or an "active" computer task that may or may not influence my own snacking behaviour.
4. I understand that my participation is voluntary and that I may withdraw at any time without my clinical care being affected.
5. I understand that for quality purposes my data may be accessed by authorised auditors as well as members of the research team.

ELIGIBILITY CRITERIA

1. I am fluent in English. ☐
2. I do not smoke and have not given up in the last year. ☐
3. I am not enrolled in a formal weight loss programme. ☐
4. I do not have diabetes or any other metabolic disorder. ☐
5. I am not allergic to chocolate, crisps or nuts. ☐

I am interested in participating. What must I do?

If you can tick all the criteria above and would like to participate please send the details below to us in an email: jo269@exeter.ac.uk

Name: .....

Preferred Contact Number / Email: .....

Preferred Contact Times/Days: .....

Food Training Research Study

Could a simple computer brain-training exercise help us to reduce our snacking behaviour?

You can help us to find out...

Appendix IV – Invitation Email

Subject Line: Food Training to Reduce Snacking Behaviour

Dear Colleagues,

I would like to invite you to take part in a research study that tests whether a new computer-based technique helps people to reduce their intake of snack foods. We will compare the snacking behaviour of two groups of participants; one given an 'active' and one given a 'control' computer-based task.

If you would like to participate in this study, first we would ask you to complete a short (5 minute) screening survey about your eating behaviour at the following link:

http://survey.ex.ac.uk/index.php?sid=76574&lang=en

Further information is provided in the attached 'participant information sheet' and at the link above. PLEASE DO NOT CONTACT US OR SEND YOUR CONSENT TO PARTICIPATE UNTIL WE HAVE CONTACTED YOU CONFIRMING ELIGIBILITY FOLLOWING THE SCREENING SURVEY.

My apologies if you have received this email on a previous occasion.

Kind regards,

Jamie O 'Sullivan

Trainee Clinical Psychologist

University of Exeter

Appendix V – Disinhibition Subscale

1.	When I smell something delicious I find it very difficult to keep from eating, even if I have just finished a meal.	True/False
2.	I usually eat too much at social occasions, like parties and picnics.	True/False
3.	Sometimes things taste so good that I keep on eating even when I am not longer hungry.	True/False
4.	When I am anxious I find myself eating.	True/False
5.	Since my weight goes up and down, I have gone on reducing diets more than once.	True/False
6.	When I am with someone who is overeating, I usually overeat too.	True/False
7.	Sometimes when I start eating, I just can't seem to stop.	True/False
8.	It is not difficult for me to leave something on my plate.	True/False
9.	When I feel fed up I often overeat.	True/False
10.	My weight has hardly changed at all in the last 10 years. (please ignore weight changes due to pregnancy)	True/False
11.	When I feel lonely I console myself by eating.	True/False
12.	Without even thinking about it, I take a long time to eat.	True/False
13.	While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie foods.	True/False
14.	Do you eat sensibly in front of others and splurge alone?	Never/rarely/often/always
15.	Do you go on eating binges though you are not hungry?	Never/rarely/sometimes/at least once a week
16.	To what extent does this statement describe your eating behaviour? 'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.'	Not like me/little like me/pretty good description of me/describes me perfectly

Appendix VI – Food Frequency Questionnaire (Monthly)

Please rate how often you have eaten the following foods over the previous month:

	4 or more times a day	2 or 3 times a day	Once a day	5 or 6 times a week	2 to 4 times a week	Once a week	1 to 3 times a month	Less often or never	I am allergic to this food so I avoid it
crisps									
ice-cream									
chips									
sweets									
cakes									
chocolate									
biscuits									
pastries / sweet pies									

Appendix VII – Dieting Questions

1. Are you currently dieting to lose weight? Y/N

2. Are you currently attending any weight-loss groups (e.g. Weight Watchers)? Y/N

3. Are you currently taking any weight-loss pills (e.g. Alli / Xenical)? Y/N

Appendix VIII – Food Frequency Questionnaire (Daily)

Please rate how often* you have eaten the following foods over the course of your day:

	1	2	3	4	5	6
	Not at all	Once today	Twice today	3 times today	4 times today	Greater than 4 times today
crisps						
ice-cream						
chips						
sweets						
cakes						
chocolate						
biscuits						
pastries / sweet pies						

* This refers to the number of occasions these foods have been consumed rather than the number of packets / items.

Appendix IX – Participant Information Sheet

Food Training Research Study

Patient Information Sheet

Why are we conducting this research?
The aim of this study is to test a new simple computer -based technique that may help people reduce their intake of snack foods. We will compare the snacking behaviour of two groups of participants; one given an 'active' and one given a 'control' computer -based task.

Why am I being invited to participate?
You have been invited to take part because you have previously participated in an online screening survey, which indicated that you eat snack foods at least weekly and that you have access to a computer.

What does the research involve?
This study involves 3 sessions with a researcher; the first two lasting 30 minutes and the final one lasting one hour. These sessions can take place in your home/work at your convenience. The study also requires some short tasks to be undertaken at home.

In the first session (30 minutes), a researcher will visit you to explain the study and ask you to rate some of your food preferences. You will then be asked to record your daily snack food intake using a very short questionnaire for one week, and to complete a food diary describing what you have eaten over the preceding 24 hours on two separate occasions. After the first week, the researcher will visit you again (for 30 minutes) to show you the computer-based 'brain training' task, which lasts 15 minutes. You will then be asked to complete the computer -based task on 4 more consecutive days at your convenience. We will also ask you to record your daily snack food intake and the food diary (again, on two occasions) for a second week. In the final session (60 minutes), the researcher will visit you and ask you to complete some food rating tasks and the computer -based task once more.

What will happen to my data?
It will be used in an anonymous form to examine whether the new computer -based technique is associated with reduced snack food intake. Where appropriate, the results of this study will be presented at medical and scientific conferences and published in journals. You will not be identified in any report or publication. The results of this study will also help us to develop future research projects and interventions aimed at reducing food intake.

Do I have to take part in this study? No, participation is entirely voluntary and separate from any previous research involvement. Your decision will not affect your clinical care at all.

Will this study be anonymous? In order to complete the study, the researchers involved will need to contact you. We therefore ask you to return the reply slip overleaf or email your contact details to the lead researcher if you wish to take part. Any information about your identity obtained from this research will be kept strictly confidential and will be stored separately to the main data in a secure, locked filing cabinet accessed only by the study researchers. The main data collected from you during the course of this research will only be linked to your participant number and will therefore be anonymous.

How can I find out more about this project?
For more information about this project please contact :
Name: Jamie O'Sullivan or Natalia Lawrence
Organisation: University of Exeter
Email: jo269@exeter.ac.uk Telephone: 01392 724672

Who is funding and organising this research?
This project is managed by the University of Exeter and is funded by the Wellcome Trust.

Who has reviewed this study? This Project has been reviewed by the University of Exeter Psychology Department's Research Ethics Committee.

Appendix X – Taste Test

We would like to know your opinion about two products. Therefore, you will now be presented 2 bowls: 1 bowl contains chocolate buttons and 1 contains crisps. You will have to rate the taste of these products by answering the questions below. Please try to give an elaborate answer and really think about the taste of the product. You can taste as much of the products as you want, as we will throw out the food that is left over at the end of this session. You will be given 15 minutes to taste the products and to complete the additional personality questionnaires. However, please relax and take your time as you can always have extra time to finish the questionnaires at the end of the study.

Crisps

1. How sweet is the product?

2. How sour is the product?

3. How bitter is the product?

4. How salty is the product?

5. Which ingredients do you taste?

6. Do you like the taste of the product? Why?

7. How often do you consume this product?
   - About twice or more a week
   - About once a week
   - About twice a month
   - About once a month
   - Less than once a month
   - Almost never

Chocolate buttons

8. How sweet is the product?

9. How sour is the product?

10. How bitter is the product?

11. How salty is the product?

12. Which ingredients do you taste?

13. Do you like the taste of the product? Why?

14. How often do you consume this product?
    - About twice or more a week
    - About once a week
    - About twice a month
    - About once a month
    - Less than once a month
    - Almost never

General

Which product do you find the most palatable? Give each product a point on a scale ranging from 1 to 10 (1 = not at all palatable, 10 = very palatable).

Crisps:	1	2	3	4	5	6	7	8	9	10
Chocolate:	1	2	3	4	5	6	7	8	9	10

Appendix XI – Debriefing

Study title

Training Response Inhibition to Reduce Snacking Behaviour

Thanks

Thank you for participating in the current research study. We hope it was interesting. Please feel free to ask the Researcher any questions you have about what happened.

What was the purpose of the study?

The current research used a computer-based intervention to investigate whether or not training people to inhibit key press responses could be effective in helping people reduce their snack-food consumption and potentially help weight-loss. You were given either the 'active' or the 'control' version of the computer-based intervention. We can tell you more details about these two versions of the intervention, and which one you received, once we have completed data collection for this study.

During the study, we offered you some food to eat in a taste test. The amount of food you ate was probably related to some important factors such as how hungry you were and whether you had been exposed to food pictures in the computer-based intervention. We are interested in whether your performance on the computer task is related to how much food you ate. In order to examine this we needed to measure how much you ate by weighing the food before and after it was offered to you. You were not informed about this part of the study before as it may have affected how much you ate. Please ask the researcher if you have any questions about this.

We also measured changes in pleasantness ratings associated with specific snack-foods to investigate the possible effects of the inhibition computer task.

Please note that the data analysis can be very lengthy and time-consuming, so the Researcher may not be able to give you any immediate feedback as to what the data shows. However, once testing of all participants and data analysis has been completed, we would be happy to email you a summary of the findings.

The researchers involved in this project do not have expertise in clinical diagnosis of mental health disorders as they are researchers and not qualified clinical psychologists. Therefore, you should not regard completion of the mood questionnaire as a clinical screening procedure. If you want help for any personal issues then please contact your GP or consider contacting the Samaritans.

What will happen to the results of the research study?

Where appropriate, the results of this study will be presented at medical and scientific conferences and published in journals. You will not be identified in any report or publication.

What do I do if I am unhappy with the way I was treated or with something that happened to me?

If you were unhappy with any element of this research study then please speak with any one of the researchers involved and we will do our best to address your concern.

Who has reviewed the study?

This study has been reviewed and approved by the Psychology Department Ethics Committee at the University of Exeter.

Follow-up

We would like to invite you to complete a follow-up session in 4 weeks time again which will last approximately 5 minutes and may be done over the phone or email. Please indicate to the researcher if you would be willing to do this.

If you have any questions at this point, please ask the researcher and he/she will do their best to respond to your queries.

Feedback / debrief interview

We welcome any feedback you can give us regarding your experience as a participant in this research study and have a few questions that we would like to ask you. Answering these questions is entirely voluntary.

Task awareness questions
(1) How did you find the computer training task? (Easy/hard/interesting/boring)?

(2) In the computer task did you notice anything in particular*?*

(3)For example, did you notice anything about when you had to not press a key? (if "no", then 4)

(4) Did you think that the stop signals (bold lines) were distributed evenly? (if not, what kind of pictures do you think were associated with the stopping response)?

(5) Do you think that the task influenced your snacking during the week or during today's session (in the taste test)?

Feedback on the computerised training

(6) Did you experience any problems accessing and/or interacting with the training task online?

(7) Were the instructions clear and easy to follow throughout?

(8) Would you be prepared to continue doing this kind of computerised training intervention for a longer period of time? (if possible estimate how long for / how frequently would you do it?)

(9) Do you think this kind of computerised training intervention would be acceptable on a smart phone? (i.e. Would you be prepared to do it on a smart phone, in a public place etc? What problems / barriers can you envisage with this?)

(13) Do you have any feedback / ideas on how we could make the task better / more engaging?

(14) What did you find helpful or unhelpful during participating in this study? (i.e. What kept you motivated to stay in / or cause you to drop out of the study)?

(15) Would you recommend trying this training to friends who wanted to eat fewer snack foods?

Checks for data analysis
(15) Do you have any history of eating disorders? (If possible current - brief questions from the MINI)

(16) And what time was it when you last ate anything? (Not including crisps!)

Finally, the last thing I need to do is just to measure your height and weight again if that's ok?

Height:	
Weight:	

Appendix XII – Supplementary Table

Mean Values of Outcome Variables between Conditions

	Week 1 (fNoGo)	Week 2 (fNoGo)	Week 1 (cNoGo)	Week 2 (cNoGo)
Weight (kg)	83.59 (14.95)	82.93 (14.95)	80.69 (15.65)	80.79 (15.74)
Liking (unhealthy-task)	66.78 (14.49)	64.94 (14.44)	62.62 (14.84)	64.41 (14.26)
Liking (healthy-task)	56.31 (14.13)	55.03 (12.58)	56.19 (13.92)	55.87 (14.67)
Liking (unhealthy-novel)	68.63 (14.17)	66.44 (14.64)	68.65 (14.78)	68.35 (14.99)
Liking (healthy-novel)	65.26 (12.65)	64.4 (11.4)	65.66 (16.02)	64.6 (15.82)
Attractiveness (unhealthy-task)	49.64 (14.23)	48.83 (14.71)	48.36 (12.42)	45.39 (15.82)
Attractiveness (healthy-task)	53.15 (12.29)	55.29 (11.78)	50.62 (11.12)	53.27 (9.27)
Attractiveness (unhealthy-novel)	48.64 (15.47)	50.21 (12.46)	46.61 (13.29)	45.69 (14.65)
Attractiveness (healthy-novel)	51.66 (16.8)	52.89 (12.81)	50.52 (13.71)	50.88 (12.59)
Daily Snacking (FFQ - total)	44 (8.56)	43.59 (8.47)	45.43 (9.34)	43.5 (8.32)
Calorie intake (24-hour)	2270.94 (538.21)	2026.87 (565.42)	1967.02 (499.92)	1987.14 (667.99)
Calorie intake (taste test)	Active 181.28 (196.07)	Control 152.26 (124.06)	N/A	N/A
Task awareness (% of sample)	Active 48	Control 2	N/A	N/A

Note. Standard deviations are presented in parentheses. fNoGo = food go/no-go task, cNoGo = control go/no-go task. N/A = Not Applicable.

Appendix XIII – Dissemination Plan

The outcome of the current research will be disseminated through the following avenues:

- Internal departmental presentation (University of Exeter)
- Presentation at NHS Trust research dissemination seminar
- Discussion with Clinical Psychologist within NHS obesity service regarding potential benefit of intervention to sufferers of obesity. This may also facilitate recruitment for future trials.
- Supervisor presenting results at British Feeding and Drinking Group annual meeting (April 2014) and British Association for Psychopharmacology annual meeting (July 2014).

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