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Food-related inhibitory control training reduces food liking but not snacking frequency or weight in a large healthy adult sample

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Abstract

Inhibitory control training has recently been used as an intervention to aid healthy eating and encourage weight loss. The aim of this pre-registered study was to explore the effects of training on food liking, food consumption and weight loss in a large (n=366), predominantly healthy sample. Participants received four training sessions within a week, in which they had to inhibit their responses to either energy-dense foods (active group) or non-food images (control group). Subjective food ratings, food consumption frequency and weight were measured pre- and post-training. At two-weeks post-training, the active group reported a greater reduction in liking for energy-dense foods, compared to the control group. Active participants also reported a significantly greater increase in healthy food liking, immediately post-training, relative to the control group. There was no statistically significant difference between groups for the change in consumption of trained foods or for weight loss. These findings are partially consistent with previous research conducted in smaller, more overweight samples. Exploratory analyses suggest that some effects of training may be driven by awareness effects. Methodological differences across findings and avenues for future investigation are discussed.

Keywords: Response inhibition; Cognitive training; Disinhibition; Food liking; Food consumption; Weight loss;

Introduction

Overweight and obesity remains a global epidemic with substantial personal and economic implications (Bray, Nielsen, & Popkin, 2004; Fry & Finley, 2007; Mokdad et al., 2003; Ng et al., 2014; WHO, 2018). The abundance and variety of palatable, energy-dense foods are often cited as a leading cause of overeating (Cummins & Macintyre, 2006; Jeffery & Utter, 2003). Despite living in such an ‘obesogenic environment’ there is considerable variation in weight status across individuals. While some can easily resist temptation and maintain a healthy weight, others face a constant battle to control their food intake.

Dual process models argue that such variation in individual susceptibility can be explained by the interaction of two cognitive systems that we all possess (Strack & Deutsch, 2004). One ‘reflective’ system is driven by conscious thought and deliberation, resulting in reasoned action that is consistent with one’s long term goals. The other ‘impulsive’ system, however, is driven by our hedonic needs and desires and can result in impulsive action with little-to-no thought of the consequences. For overeating, it is thought that behaviour is determined by a weak reflective system and/or a strong impulsive system (e.g. Houben, Nederkoorn, & Jansen, 2012; Lawrence, Hinton, Parkinson, & Lawrence, 2012; for a review see Stice, Lawrence, Kemps, & Veling, 2016). Individuals who are overweight or obese have been shown to demonstrate poor self-control and increased impulsivity across a range of questionnaires and behavioural measures, and in particular, they have been shown to demonstrate these characteristics in relation to food (Batterink, Yokum, & Stice, 2010; Chalmers, Bowyer, & Olenick, 1990; Davis et al., 2008; Davis, Patte, Curtis, & Reid, 2010; Houben, Nederkoorn, & Jansen, 2014; Lavagnino, Arnone, Cao, Soares, & Selvaraj, 2016; Nederkoorn, Coelho, Guerrieri, Houben, & Jansen, 2012; Nederkoorn, Smulders, Havermans, Roefs, & Jansen, 2006;). Houben et al. (2014) demonstrated such a deficit in food-related self-control when they found that increased body mass index (BMI) was associated with poor inhibitory control in response to images of energy-dense foods but not to general stimuli.

Such findings have sparked interest in developing new behavioural interventions to aid reduced energy intake and weight loss by targeting these two cognitive systems (Jones, Hardman, Lawrence, & Field, 2018; Turton, Bruidegom, Cardi, Hirsch, & Treasure, 2016). One intervention that has been used with some degree of success is food-related inhibitory control training, with recent meta-analyses citing small-to-medium effect sizes when compared to control training (Allom, Mullan, & Hagger, 2016; Jones et al., 2016). In a typical inhibitory control training paradigm, participants are presented with relevant stimuli, such as images of unhealthy foods, and are instructed to make a speeded response to each stimulus, but to withhold that response when a signal occurs. In order to bias behaviour towards healthy eating, for example, healthy foods are associated with a response (go foods) and unhealthy foods are paired with a stop or no-go signal (no-go foods). Repeatedly pairing a stimulus with the inhibition of a response has been demonstrated to improve the ability to stop to that stimulus on future trials (Verbruggen & Logan, 2008). In the case of food-related inhibition training, repeatedly stopping to unhealthy foods has also been shown to influence

eating behaviour. Studies have shown effects of training on reduced calorie consumption (Adams, Lawrence, Verbruggen, & Chambers, 2017; Houben, 2011; Houben & Jansen, 2011, 2015; Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015a; Oomen, Grol, Spronk, Booth, & Fox, 2018; Veling, Aarts, & Papies, 2011), decreased unhealthy food choices (van Koningsbruggen, Veling, Stroebe, & Aarts, 2013; Veling, Aarts, & Stroebe, 2013a, 2013b) and even weight loss (Lawrence et al., 2015b; Veling, van Koningsbruggen, Aarts, & Stroebe, 2014).

Several mechanisms have been proposed to explain the effects of inhibitory control training on behaviour with the most evidence to date supporting stimulus devaluation (Driscoll, de Launay, & Fenske, 2018; Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017a, but see Jones et al., 2016), which is the primary focus of this study. It has been shown that repeatedly pairing a stimulus with the inhibition of a response can lead to a reduction in rated valence for that stimulus; an effect that has been demonstrated across a range of stimuli including faces, arbitrary shapes, sexual images, alcohol and food (Doallo et al., 2012; Driscoll et al., 2018; Houben, Havermans, Nederkoorn, & Jansen, 2012; Lawrence et al., 2015b; Veling et al., 2013a; Wessel, O'Doherty, Berkebile, Linderman, & Aron, 2014). A number of explanations for this devaluation effect have been proposed (Veling et al., 2017a), including the "Behaviour Stimulus Interaction" theory whereby devaluation occurs in order to reconcile the conflict between the automatic approach response elicited by rewarding stimuli and the need to inhibit that response. Another suggestion is that during training, associations are created between the food stimuli and inherent appetitive/aversive 'centres' (McLaren & Verbruggen, 2016; Verbruggen, Best, Bowditch, Stevens, & McLaren, 2014). Associative learning theories have argued that hard-wired associations exist between actions and appetite/aversion, whereby stopping and avoidance are linked to an aversive system and responding and approach are linked to an appetitive system (Chen & Bargh, 1999; Dickinson & Balleine, 2002; Dickinson & Dearing, 1979; Guitart-Masip et al., 2012; Konorski, 1967). It is plausible therefore that associations between going and stopping and the respective appetitive/aversive 'centres' can spillover to food stimuli presented during inhibition training. This would suggest that the associative link between foods, action tendencies and the appetitive/aversive centres may be strengthened throughout training such that no-go foods become increasingly disliked and go foods increasingly liked (see Jones et al., 2016).

In a study investigating the effect of inhibition training and appetite on food choice, Veling et al. (2013b) paired palatable, energy-dense, foods with either a go cue or a no-go cue in a within-subjects design. Participants then rated the foods according to attractiveness and tastiness before selecting three of the foods for consumption. Their results demonstrated that participants with a high appetite rated the no-go foods less favourably (a combined measure of attractiveness and tastiness) and were less likely to select those foods, compared to the go foods. Furthermore, the effect of appetite on food choice was mediated by the devaluation of no-go foods, although, there was no evidence of mediation for the evaluation of go foods. In a similar study, with a community sample who were predominately overweight or obese, Lawrence et al. (2015b) also demonstrated the devaluation of energy-dense foods following inhibition training in a between-groups design. For this study, participants completed four

sessions of go/no-go training over a one-week period. The active task involved responding to images of healthy foods (go foods) and withholding responses to images of energy-dense snack foods (no-go foods). The control task, conversely, consisted solely of non-food images; participants were trained to respond to some household items and to stop to others. Measures of weight loss, snacking frequency and energy intake were recorded along with ratings for the liking and attractiveness of the trained foods. Lawrence et al. found that participants in the active group lost a significant amount of weight and reduced their daily energy intake, relative to the control group. They also showed a significant reduction in liking for energy-dense snack foods from pre- to two weeks post-training; this is compared to the control group who showed a slight increase in liking over the same time period. Although the active group were also trained to repeatedly respond to healthy foods, there were no group differences in either liking or attractiveness ratings for these foods. This finding is in contrast to recent results showing that similar training methods can also bias behaviour towards healthy eating.

Training participants to respond to certain foods using a go-cue (cued-approach training) has been shown to result in increased choice behaviour and valuation of those foods (Chen, Holland, Quandt, Dijksterhuis, & Veling, 2019; Chen, Veling, Dijksterhuis, & Holland, 2016, 2018a; Schonberg et al., 2014; Veling et al., 2017b; Zoltak, Veling, Chen, & Holland, 2018). In a series of experiments, Chen et al. (2016) investigated the effect of inhibition training on stimulus devaluation by pairing foods (both healthy and unhealthy) with a go cue, a no-go cue or no cue. Participants rated each of the foods according to how attractive they were, at that moment in time, pre- and post- training. These ratings were then compared across conditions and also to stimuli that were not presented during training (untrained foods). In addition to the expected effects on devaluation for no-go foods, Chen et al. also found evidence for increased ratings of go foods, relative to untrained foods. To see whether such effects would translate to behaviour, Veling et al. (2017b) used a food choice task, comparing equally valued foods that had been associated with either a cued response (cued go foods) or no response (non-cued no-go food). Their results showed that participants were more likely to choose go foods, compared to no-go foods. Moreover, these effects were demonstrated when comparing both energy-dense snacks and fruits and vegetables. These findings were later replicated in a series of seven pre-registered studies (Chen et al., 2019). Furthermore, it was shown that training could be used to promote healthy foods over unhealthy foods (when a choice between healthy cued-go and unhealthy cued-no-go foods was compared to a choice between healthy and unhealthy untrained foods). Together these results suggest that go/no-go training can also be used to increase food preferences and choice behaviour, even for healthy foods.

The current study followed the methods used by Lawrence et al. (2015b), but in a much larger, less selective sample that was predominantly of healthy weight. Our primary aim was to replicate previous results showing effects of go/no-go training on reduced liking for energy-dense no-go foods (Lawrence et al., 2015b; Veling et al., 2013a). We focused on food devaluation because it seems to be a robust outcome, even in healthy-weight samples such as ours, and we had planned to examine the influence of individual differences (see below). Participants were randomly assigned to receive either active training, in which energy-dense

foods were paired with inhibition (100% cued no-go) and healthy foods were paired with responding (100% go), or control training, which included only non-food stimuli (where half the images were 100% go and half were 100% no-go). The training schedule involved four ten-minute sessions over a one-week period. Our primary outcome measure was a subjective liking rating for each food at two weeks post-training (as measured in Lawrence et al., 2015b), but we also measured changes immediately after the first training session (i.e. similar to single-session studies such as Chen et al., 2016). Participants were therefore asked to rate trained and untrained foods at pre-training, immediately after a single training session, and at two weeks post-training. Effects on healthy food liking were also measured along with food consumption frequency and weight loss. Participants were able to complete the study either entirely online or with two lab sessions at the beginning and end of the study. It was hypothesised that active training would reduce self-reported liking of energy-dense foods from pre- to two weeks post-training, relative to control training (primary outcome). In addition, we predicted increased liking of healthy (go) foods, reduced consumption frequency for trained (no-go) snack foods and increased weight loss in the active group, compared to the control group, as measured at two weeks post-training. We also expected similar changes in food liking immediately after the first training session. All hypotheses, methods and statistical analyses were pre-registered for transparency and are available online¹. The current study was part of the GW4 Undergraduate Psychology Consortium which aims to promote collaborative and reproducible science for undergraduate students (Button, Chambers, Lawrence, & Munafò, 2019). Several measures of individual differences (e.g. self-esteem, self-efficacy, emotional regulation) were included for pedagogical reason as part of the student project to test moderation effects of training. These moderation analyses are not presented in the current paper (see Deviations from Pre-registered Protocol).

Method

Participants

A total of 431 participants took part in the study (337 female; age: $M=24.51$, $SD=11.38$; see Figure 1). For laboratory-based sessions participants were recruited from three University campuses (Cardiff University, University of Bath and University of Exeter) using research participation schemes and word of mouth. For the online arm of the study participants were recruited using social media (e.g. Facebook, Twitter). The study was presented as testing “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 ‘training’ task.” Based on our pre-registered criteria, 30 participants were excluded from the analysis due to ineligibility according to age (1 participant aged below 18 years) or body mass index (BMI; 29

¹ <https://osf.io/wxyra/>

participants with a BMI <18.5). Due to the potential influence of training on weight loss we excluded participants with a BMI in the underweight range (<18.5; Lawrence et al., 2015b). A further 35 participants were excluded for not having any training data or for having duplicate identification numbers (n=4). The final sample size was 366; data for 308 participants were included in the two weeks post-training analysis (data was missing for 58 participants due to attrition) and data for 312 participants was analysed for the immediate post-training outcomes (there was no session 1 post-training data for 54 participants due to attrition or technical issues). Ethical approval for the trial was granted by the Psychology Department Board of Ethics at the University of Exeter (initially, and all participating institutions thereafter).

Sample Size and Statistical Power

Sample size was determined using *a priori* power calculations based on Lawrence et al.'s (2015b) finding for the effect of training on changes in energy-dense food liking ($d=.55$). With 80% power and a two-tailed alpha of .05, a sample size of 106 was required to detect an effect size of $d=.55$ (53 per group; calculated using G*Power; Faul, Erdfelder, Lang, & Buchner, 2007). This sample size was exceeded in an attempt to power for additional moderators that were included as part of the student consortia project (see Deviations from Pre-registered Protocol). The final sample was 366 before missing data considerations. Sensitivity analyses for the main comparisons revealed that we had 80% power to detect an effect size of $d=.32$ at both time points (for two weeks post-training, timepoints 1-3; N=308; 167 active, 141 control; immediately post-training, timepoints 1-2; N=312; 166 active, 146 control).

Deviations from Pre-registered Protocol

Additional moderators (binge eating behaviour, self esteem, self efficacy, restrained eating, disinhibited eating, emotional regulation) were added by the students so that each could demonstrate individual input into the design, and answer a unique question for their empirical project (BPS, 2019; Button et al., 2019). We also pre-registered our plan to explore the moderating role of baseline BMI and food consumption frequency. The calculated sample size was multiplied fourfold in the pre-registered analysis to account for these analyses (424; Leon & Heo, 2009). However, with time and resource limits this target sample size was not reached, post exclusions. Due to insufficient statistical power these moderators are not included in the analyses but all data are available online¹.

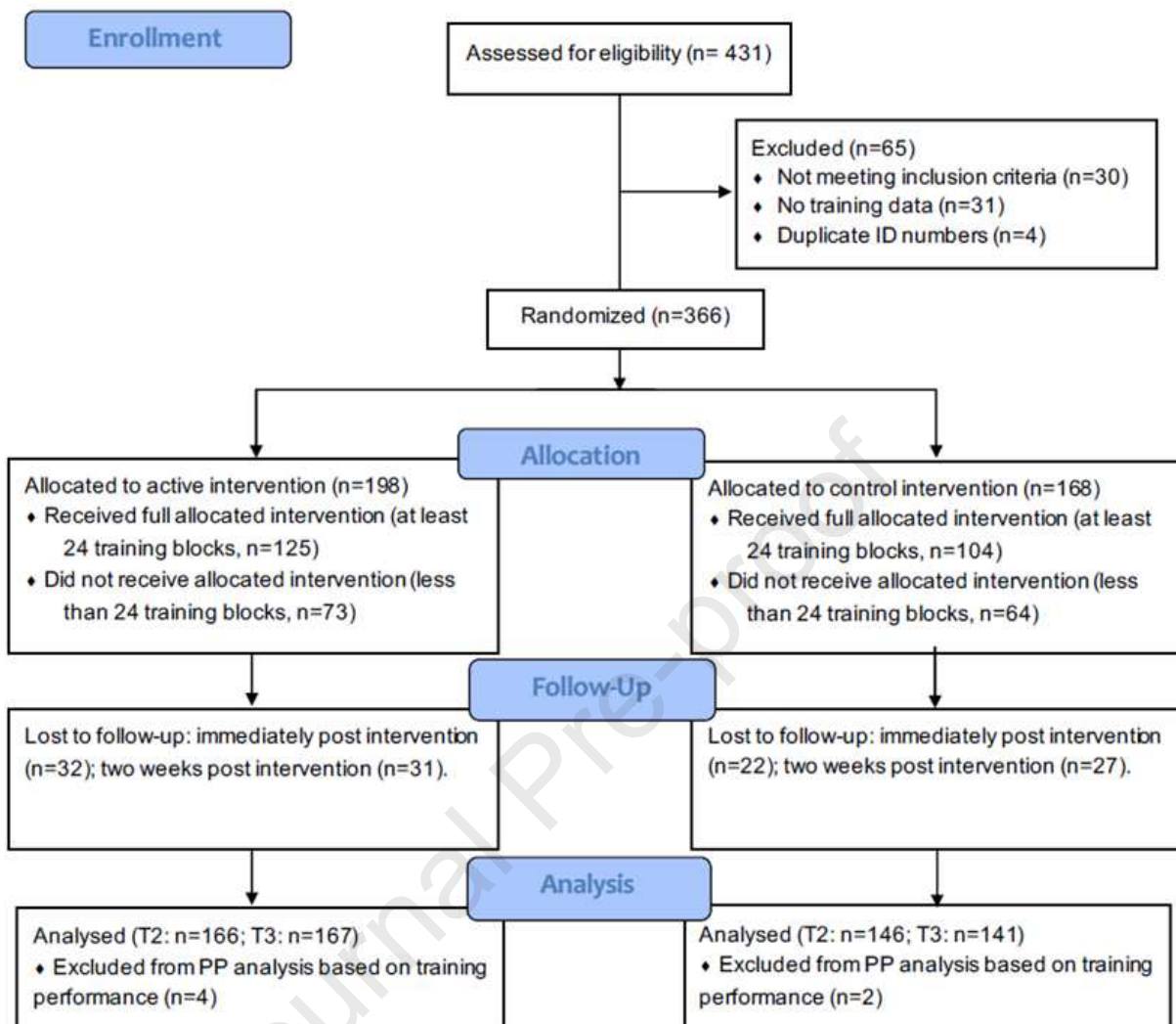


Figure 1. Recruitment flow diagram showing numbers of participants included in each intervention group at each stage of the study (see Supplementary Information for details of each sample).

Note. T2 = timepoint 2 (immediately post-training); T3 = timepoint 3 (two weeks post-training); PP = per protocol

Procedure

An overview of the study procedure is provided in Figure 2 and details of all measures and materials are provided below. In the first session, participants provided consent and demographic information. They then completed measures of food liking and food consumption frequency before answering questions on their height and weight. Participants were then presented with a series of individual differences questionnaires as part of the student consortia element of the study. Following these questionnaires, participants were directed to the training task in a separate browser window. At this point they were randomly allocated to the active or control training by the computer program. To complete the first session, participants answered post-training measures of food liking (immediately post-

training; timepoint 2) and if participants were attending a laboratory session their height and weight was measured by a researcher. Participants were then asked to complete the training task at home over the next three consecutive days. Two weeks after the first session participants were asked to complete self-reported weight, food liking and food consumption frequency (two weeks post-training; timepoint 3). They then answered a series of debrief questions and were provided with a full debrief of the study's aims. If participants were in the lab they were weighed by one of the researchers.

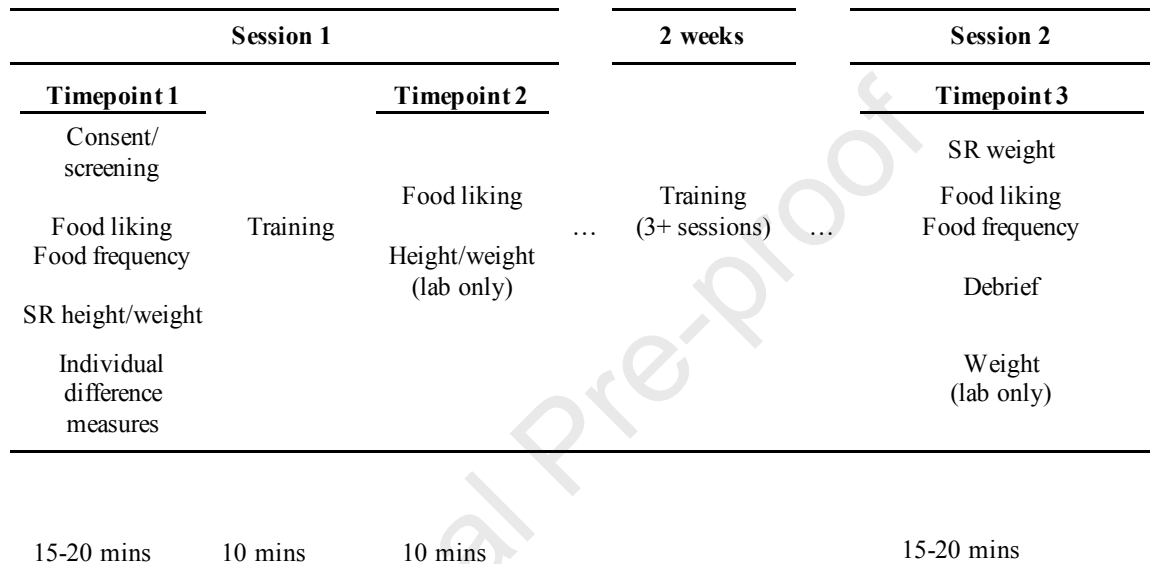


Figure 2. Schematic diagram of the study procedure. In session 1 participants completed baseline outcome measures, including food liking, food consumption frequency and self-reported (SR) weight. As part of the student consortia project, they also completed measures of individual differences. They were then randomly assigned to active or control training before completing the immediate post-training outcome measures (timepoint 2). Participants were asked to complete three training sessions at home over the following week before the second session, two weeks later. In session 2 they completed post-training outcome measures and were debriefed.

Materials/Measures

Training

The training task was a modified version of the go/no-go task and is identical to that used by Lawrence et al. (2015b). The task lasted approximately 10 minutes and consisted of six blocks of 36 trials. Each block randomly presented one each of 36 food and non-food images. The active task included 9 energy-dense food images (biscuits, chocolate, crisps, cake; >4kcal/g), 9 healthy food images (fruit, vegetables, rice cakes) and 18 non-food filler images (clothes; jeans, shirts, jumpers, socks, skirts and ties). The control version used the same filler images in addition to 18 images of household objects (furniture, stationery, gardening tools).

Food and non-food images were presented against a white background and were matched as closely as possible for size, colour and visual complexity. All images and experimental materials are available from the authors on request.

Each trial began with a central black rectangle presented against a white screen (1250 ms; Figure 3). Images were then presented, within the rectangle, to either the left or right hand side (1250 ms). Participants were instructed to press the ‘C’ and ‘M’ keys, respectively, as quickly and as accurately as possible (using a standard keyboard; go trial). On half of the trials, the rectangle was bold indicating that the participant should withhold their response (no-go trial). In the active task, 100% of energy-dense foods were no-go trials and 100% of healthy foods were go trials (i.e. food images were consistently associated with no-go and go responses, respectively). The filler images were 50% no-go trials and 50% go trials (i.e. inconsistently associated with no-go and go responses). In the control task, certain household objects (DIY tools, gardening tools and stationery) were 100% no-go trials and certain objects were 100% go trials (electrical items, furniture and buckets; i.e. consistent mapping). The filler images were 50% no-go and 50% go (i.e. inconsistent mapping). Breaks were provided between blocks and feedback was presented to increase motivation (accuracy and mean go RT).

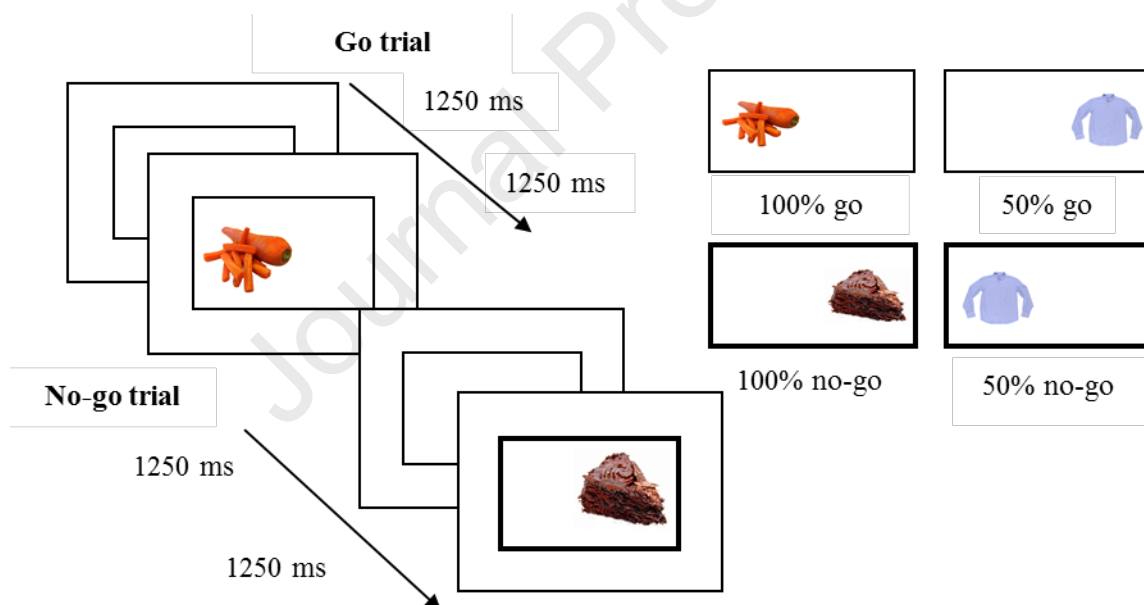


Figure 3. A) Display sequence for the training task. For go trials a fixation rectangle was presented, followed by a stimulus on the left or right hand side. Participants were instructed to respond to the stimulus location using the ‘C’ and ‘M’ keys, respectively. For no-go trials, the rectangle was bold, indicating that the participant should withhold their response. **B)** Mapping for the stimuli to go and no-go trials in the active task; energy-dense foods: 100% no-go; healthy foods: 100% go; filler images: 50% no-go, 50% go.

Food Liking

Subjective food liking ratings were measured using 100-point visual analogue scales (VAS; presented in Qualtrics, Provo, UT). Each food from the training task was included plus an additional 9 untrained foods (dried fruit, a sandwich, soup, pizza, jacket potato with butter, mushrooms, quiche, pancakes, and vegetarian cannelloni; food images were identical to those in Lawrence et al., 2015b). Each trial presented a single food image above a slider. Participants were instructed to imagine that some of the food was in their mouth and to rate the image according to how much they liked the taste. The slider used the anchors ‘not at all’ and ‘very much’; the slider was initially positioned at 50 for each food. Trials were self-timed and the order of images was randomised.

Food Consumption Frequency

Participants were asked to indicate how often they consumed each of the foods presented during training plus four additional categories for ice-cream, chips, sweets, and pastries / sweet pies (untrained foods). Ratings were made on a 9-point scale (scoring from 8 down to 0) according to how often they had been consumed within the last 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; Churchill & Jessop, 2011). All foods were presented simultaneously in fixed order (Qualtrics, Provo, UT).

Weight and BMI

As part of the online survey, participants were asked to self-report their height and weight. In the laboratory sessions, participants were also asked whether the researcher could record their height and weight using a tape measure and set of bathroom scales. All weights were converted to kg and BMI was calculated (weight [kg]/ height² [m]).

Debrief Questions

At the end of the study participants were asked a) whether they thought the training helped to reduce their food intake, and b) would they recommend the training to a friend who was trying to reduce their food intake. Both questions allowed participants to respond ‘yes’, ‘no’ or ‘not sure’. They were also asked to guess whether they thought they were in the active or the control condition (dichotomous choice) and whether they had any additional comments for how the training affected them or how it could be improved (all comments are available online¹).

Individual Difference Measures

Several questionnaires were included in the study as part of the student consortia project. These questionnaires were included to see whether certain personality traits moderated the effect of training on outcomes. Due to insufficient statistical power these measures were not included in the analyses and will therefore only be described briefly (see Deviations from Pre-registered Protocol). Data from these questionnaires is provided online¹. The following questionnaires were presented in a randomised order: the Binge Eating Scale (Gormally, Black, Daston, & Rardin, 1982); the Three-Factor Eating Questionnaire (Disinhibition subscale only; Stunkard & Messick, 1985); Rosenberg’s Self-Esteem Scale (Rosenberg, 1965); the

General Self-Efficacy Scale (Schwarzer & Jerusalem, 1995); the Dutch Eating Behavior Questionnaire (Van Strien et al., 1986); the Emotional Regulation Questionnaire (Gross & John, 2003). The Binge Eating Scale, the Three-Factor Eating Questionnaire – Disinhibition subscale and the Dutch Eating Behavior Questionnaire – restraint subscale were analysed to ensure that there were no differences between our training groups on these measures of eating behaviour.

Statistical Analysis

As outlined in our pre-registered protocol, all participants who met eligibility criteria, and for whom change scores could be calculated, were included in the analysis in the groups to which they were randomised irrespective of how much training they had completed. In accordance with our previous research (Adams et al., 2017; Lawrence et al., 2015b) we also excluded six participants who did not perform as expected during training in a per-protocol analysis (based on proportion of errors for go and no-go trials and mean reaction time for go trials). This analysis did not change the pattern of results and the full details can be found in the Supplementary Information.

Following our pre-registered protocol¹, our primary analysis was for change in energy-dense liking ratings from pre- to post-training. To replicate Lawrence et al. (2015b), this is based on change scores from baseline to two weeks post-training (timepoints 1-3). We have also analysed immediate post-training changes to consider single-session training effects consistent with other lab-based studies (timepoints 1-2). Secondary outcomes include changes in healthy food liking, food consumption frequency and weight. Mean scores were calculated by averaging across each food type for liking scores and across the four no-go foods (biscuits, chocolate, crisps, cake) for food consumption frequency. For weight measures we had two variables: self-reported weight and experimenter-recorded weight for lab participants only. The correlation between these two weights in lab participants was very high (at baseline $r(214) = .97, p < .001$; at post-training $r(169) = .92, p < .001$), suggesting self-reported weights were valid. To calculate weight change we used experimenter-recorded values where both pre- and post-training values were available (150/289; 51.9%), otherwise, self-reported values were used (139/289; 48.1%). Some participants were excluded from this analysis based on extreme change scores (values $> \pm 7\text{kg}$, $n=19$). For all change scores, pre-training values were subtracted from post-training values such that negative scores reflect reductions in these outcome measures.

All outcomes were analysed using pre-registered simple linear regressions. The number of completed training blocks (range: 6-54; $M=21.76$; $SD=6.82$) was also added to these models to investigate whether there was a ‘dose-response’ relationship between training and each outcome measure. We also pre-registered a 2 x 3 mixed ANOVA (between subjects factor: *condition* [active, control]; within subjects factor: *food type* [energy-dense, healthy, untrained]) to further investigate changes in food liking according to food type and training

condition. This complements our more focused linear regressions conducted separately for unhealthy and healthy foods. Details of exploratory analyses are provided in the results section below, and further analyses comparing lab-based and online training can be found in the Supplementary Information. All analyses were carried out using SPSS 25 (IBM Corp, 2017) and all study data is provided online¹.

Results

Group Differences

There were no significant differences between the two groups for sex ($\chi^2(1)=.48, p=.49$), age, baseline BMI, baseline consumption of trained energy-dense foods, BES, TFEQD or DEBQRE (all t s <1.4 , all p s $>.16$, all d s $<.15$; see Table 1).

Table 1. Group characteristics and training data with between-group significance tests (SD within parentheses).

	Active (n=198)	Control (n=168)	t	p
Sex (% female)	76.8	79.8		
Age	23.69 (10.18)	24 (10.88)	.28	.78
Baseline BMI	23.57 (3.84)	23.78 (4.78)	.46	.65
FCF-energy-dense	2.96 (0.9)	2.83 (0.84)	1.4	.16
BES	15.21 (5.95)	14.81 (6.4)	.62	.53
TFEQD	7.33 (3.96)	6.95 (3.47)	1	.32
DEBQRE	2.72 (0.88)	2.73 (0.86)	.13	.89
# training blocks	20.75 (7.93)	20.53 (7.35)	.27	.79
Proportion no-go errors	.06 (.1)	.06 (.11)	.17	.86
Proportion go errors	.03 (.06)	.02 (.05)	.62	.54
GoRT	527.18 (90.05)	513.7 (76.12)	1.53	.13

Note. BMI = body mass index; FCF = Food consumption frequency; BES = Binge Eating Scale; TFEQD = Three Factor Eating Questionnaire – Disinhibition scale; DEBQRE = Dutch Eating Behavior Questionnaire – Restrained Eating scale; GoRT = go reaction time

Training Performance

On average, participants completed 20 out of the requested 24 blocks of training ($M=20.65$, $SD=7.66$, range: 6–54) and 62.6% completed the four training sessions. Importantly, there was no statistically significant difference between groups for the number of completed training blocks ($t(364) = .27$, $p=.79$, $d=.03$; see Table 1). Participants also showed good performance on the training tasks; the proportion of errors was low (no-go: $M=.06$, $SD=.1$; go: $M=.02$, $SD=.05$), indicating that participants engaged well with the training.

As in our previous studies, we examined the training data to check for evidence of learning stimulus-response associations. Such learning would be demonstrated with reduced errors and/or reaction times for the consistently associated stimuli compared to the inconsistently associated stimuli (e.g. comparing the 100% no-go energy-dense items with the 50% no-go filler items, and the 100% go healthy items with the 50% go filler items in the active group). Due to the large variation in the number of completed training blocks we analysed the first session only (6 blocks) and overall performance. Evidence of learning stimulus-response associations was found for both analyses in the no-go errors and go reaction times. The results showed that the mean proportion of no-go errors was significantly lower for the stimuli consistently paired with stopping compared to the inconsistent (filler) stimuli (both $F_s > 40.94$, both $p_s < .001$, both $\eta_p^2 > .1$) This was not dependent on training group (both $F_s < .44$, both $p_s > .51$, both $\eta_p^2 < .001$). Go reaction times were also significantly faster for stimuli that were consistently paired with a go response compared to those that were inconsistently paired with going (both $F_s > 291.59$, both $p_s < .001$, both $\eta_p^2 > .45$). There was a statistical trend for an interaction between stimulus type and training group for session one ($p=.09$, $\eta_p^2=.008$), and this interaction was significant for overall performance ($p=.04$, $\eta_p^2=.01$). The interactions showed a greater difference between stimulus types for the active group, compared to the control group, suggesting that learning effects may have been greater in the active condition. However, pairwise comparisons showed that the difference between stimuli was statistically significant for both groups (all $p_s < .001$). There was no evidence of learning in the go error rates, which may have been due to floor effects (see Supplementary Information for the full analyses of training data).

Pre-registered Analyses

Tables 2 and 3 show all outcome means and change scores by training condition for timepoints 1 and 3 (pre-training to two weeks post-training; our primary focus) and timepoints 1 and 2 (pre-training to immediately post-training), respectively.

Table 2. Descriptive statistics for means and change scores (Δ) across timepoints 1–3 (n=308; SD within parentheses).

	Time 1		Time 3		Δ Time 1–3	
	Active	Control	Active	Control	Active	Control
Liking-Energy-dense	68.84 (16.18)	66.11 (16)	63.61 (17.07)	63.56 (16.93)	-5.22 (10.47)	-2.55 (9.42)
Liking-Healthy	58.85 (12.89)	59.7 (13.08)	60.33 (12.81)	59.37 (12.49)	1.48 (8.91)	-0.33 (7.94)
Liking-Untrained	62.86 (12.34)	65.16 (12.03)	62.14 (12.67)	63.7 (11.91)	-0.72 (7.5)	-1.46 (7.57)
FCF-Energy-dense	3 (0.9)	2.9 (0.84)	2.82 (0.87)	2.83 (0.86)	-0.18 (0.65)	-0.07 (0.62)
FCF-Healthy	4.87 (1.07)	4.74 (1.06)	4.83 (1.14)	4.76 (1.13)	.004 (0.83)	0.02 (0.58)
FCF-Untrained	2.16 (0.67)	2.23 (0.71)	2.23 (0.87)	2.27 (0.8)	0.07 (0.75)	0.04 (0.75)
Weight (kg)	67.23 (13.56)	67.99 (14.39)	66.75 (13.39)	67.73 (14.3)	-0.47 (2.03)	-0.26 (1.95)

Note. FCF = Food consumption frequency

Table 3. Descriptive statistics for means and change scores (Δ) across timepoints 1–2 (n=312; SD within parentheses).

	Time 1		Time 2		Δ Time 1–2	
	Active	Control	Active	Control	Active	Control
Liking-Energy-dense	67.97 (17.17)	65.73 (15.22)	65.95 (17.63)	64.19 (15.8)	-2.02 (7.46)	-1.55 (6.09)
Liking-Healthy	58.18 (12.53)	59.89 (13.08)	59.68 (13.16)	60.18 (13.43)	1.5 (6.12)	0.29 (3.96)
Liking-Untrained	62.16 (12.53)	65.18 (12.14)	62.1 (13.35)	65.6 (12.44)	-0.06 (4.29)	0.43 (4.74)

Changes in Food Liking

Both training groups showed a reduction in liking for energy-dense foods at two weeks post-training and this devaluation effect was significantly greater for the active compared to the control group ($r^2=.02$, $F(1, 307) = 5.46$, $p=.02$; $B = 2.67$, 95% CI [.42, 4.92]; Table 2, Figure 4). Adding the number of completed training blocks to the regression model revealed that there was no statistically significant ‘dose-response’ relationship between training and

devaluation ($r^2=.03$, $F(3, 307) = 2.81$, $p=.04$; training blocks: $B = -.34$, 95% CI $[-.84, .16]$, $p=.18$; interaction: $B = .28$, 95% CI $[-.06, .61]$, $p=.11$). A reduction in energy-dense food liking was also demonstrated for both groups immediately post-training (Table 3), and although the difference between groups was in the expected direction, this was not statistically significant ($r^2=.001$, $F(1, 311) = .37$, $p=.54$; $B = .47$, 95% CI $[-1.06, 2]$).

For healthy food liking at two weeks post-training, there was an increase in ratings for the active group and a decrease in ratings for the control group (Table 2, Figure 4). This difference in evaluative ratings was partially confirmed with a statistical trend ($r^2=.01$, $F(1, 307) = 3.45$, $p=.06$; $B = -1.8$, 95% CI $[-3.7, .11]$). We found no evidence for a ‘dose-response’ relationship when adding the number of completed training blocks ($r^2=.02$, $F(3, 307) = 1.51$, $p=.21$; training blocks: $B = .22$, 95% CI $[-.2, .65]$, $p=.3$; interaction: $B = -.14$, 95% CI $[-.43, .15]$, $p=.34$). Immediately post-training, both groups showed an increase in liking for healthy foods (Table 3); this increase was significantly greater in the active group compared to the control group ($r^2=.01$, $F(1, 311) = 4.16$, $p=.04$; $B = -1.21$, 95% CI $[-2.38, -.04]$).

To further investigate changes in energy-dense and healthy food liking, relative to untrained foods, we used a (pre-registered) 2 x 3 mixed ANOVA (between-subjects factor: *condition* [active or control]; within-subjects factor: *food type* [energy-dense, healthy, untrained]). There was no statistically significant effect of condition ($F(1, 306) = .003$, $p=.96$, $\eta_p^2 < .001$); however, there was a significant effect of food type ($F(1.83, 558.57) = 32.08$, $p < .001$, $\eta_p^2 = .1$, with Huynh-Feldt correction), and importantly, there was a significant interaction between the two ($F(1.83, 558.57) = 8.64$, $p < .001$, $\eta_p^2 = .03$, with Huynh-Feldt correction). Pairwise comparisons showed a significantly greater reduction in energy-dense food liking for the active group, compared to the control group ($p=.02$). There was also a statistical trend for a greater increase in healthy food liking in the active group, compared to the control group ($p=.06$). There was no statistically significant difference between training groups for the untrained foods ($p=.39$).

The above results were partially replicated with immediate post-training ratings. We found no significant effect of condition ($F(1, 310) = .04$, $p=.85$, $\eta_p^2 < .001$), a significant effect of food type ($F(1.75, 542.6) = 23.57$, $p < .001$, $\eta_p^2 = .07$, with Huynh-Feldt correction) and a statistical trend for the interaction ($F(1.75, 542.6) = 2.92$, $p=.06$, $\eta_p^2 = .01$, with Huynh-Feldt correction). Pairwise comparisons showed a significant difference between training groups for the healthy foods only ($p=.04$); there was no statistically significant difference for energy-dense foods ($p=.54$) or untrained foods ($p=.34$).

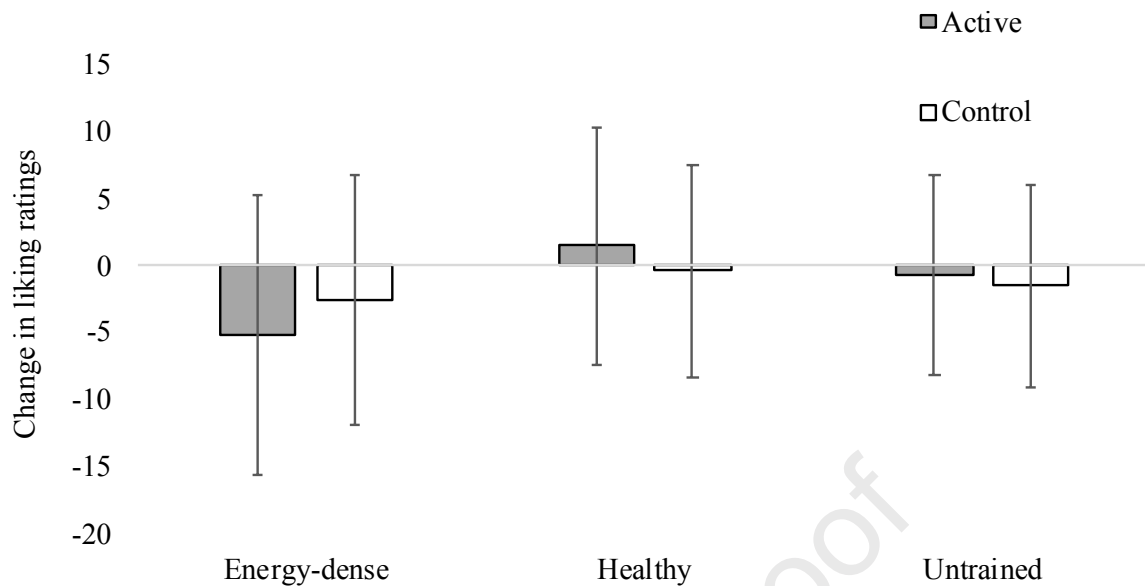


Figure 4. Changes in food liking ratings from pre- to two weeks post-training (timepoints 1-3) as a function of food type and training condition. A negative value indicates a reduction in food liking scores. Error bars: $\pm 1SD$

Changes in Food Consumption Frequency – Energy-Dense Foods

Self-reported consumption frequency for the trained energy-dense foods decreased for both groups across the two-week period (Table 2). Although, the results were in the expected direction, with the active group reporting a greater decrease than the control group, this difference was not statistically significant ($r^2 = .01$, $F(1, 307) = 2.47$, $p = .12$; $B = .11$, 95% CI [-0.03, .26]). There was also no significant effect of the number of completed training blocks ($r^2 = .01$, $F(3, 307) = .87$, $p = .46$; training blocks: $B = -.003$, 95% CI [-0.04, .03], $p = .85$; interaction: $B = .003$, 95% CI [-0.02, .03], $p = .76$).

Changes in Weight

Weight was recorded at baseline and at two weeks post-training (timepoint 3). Both groups showed a reduction in weight during this time, with a mean loss of .37kg ($SD = 1.99$; Table 2). The active group lost more weight than the control group, however, the difference between groups was not statistically significant ($r^2 = .003$, $F(1, 288) = .82$, $p = .37$; $B = .21$, 95% CI [-0.25, .68]; see Table 2). Further, there was no significant effect of the number of training blocks completed on weight change ($r^2 = .003$, $F(3, 288) = .33$, $p = .81$; training blocks: $B = -.02$, 95% CI [-0.12, .08], $p = .69$; interaction: $B = .01$, 95% CI [-0.06, .08], $p = .74$).

Exploratory analyses

Changes in Food Liking

Additional analyses were conducted to examine whether the reduction in liking for energy-dense foods in the active vs. control group varied over time, and to compare changes to trained and untrained foods within the same category (healthy or energy-dense).

To examine the devaluation of energy-dense foods over time we conducted a 2 x 2 mixed ANOVA on change scores (between subjects factor: *condition* [active or control], within subjects factor: *time* [immediately after training vs. two weeks post-training]). There was a main effect of time ($F(1, 265) = 6.25, p = .013, \eta_p^2 = .023$) with greater devaluation at two weeks ($M = -3.29, SD = 9.67$) than immediately post-training ($M = -1.83, SD = 6.91$). The effect of group approached significance ($F(1, 265) = 3.53, p = .061, \eta_p^2 = .013$), with greater devaluation in active ($M = -3.35, SD = 6.91$) than control participants ($M = -1.76, SD = 6.96$). The group x time interaction was not significant ($F(1, 265) = 2.82, p = .095, \eta_p^2 = .011$), although pairwise contrasts indicated that the difference between time-points was driven by the active ($M = -2.44, SD = 9.54, p = .003$) rather than the control group ($M = -0.48, SD = 9.53, p = 0.57$).

The pre-registered 2 x 3 ANOVA on changes in food liking found greater devaluation of energy-dense foods relative to healthy and untrained foods in the active vs. control group. However, this comparison was partly confounded by food category because go-trained foods were always healthy and no-go trained foods were always energy-dense. We therefore split untrained foods into healthy and more energy-dense categories to compare trained and untrained foods of similar types (see supplementary materials for full descriptive and inferential statistics). Separate exploratory 2 x 2 ANOVAs examined change scores for healthy and energy-dense foods (between subjects factor: *condition* [active or control], within subjects factor: *food type* [trained vs. untrained]). Results were consistent with our main analyses, suggesting significantly greater devaluation of trained vs. untrained energy-dense foods in the active vs. control group at two weeks post-training (group x food type interaction, $F(1,306) = 6.92, p = .009, \eta_p^2 = .022$; significant difference between food types in the active group $M = -3.32, SD = 10.05, p < .001$, but not in the control group $M = -0.29, SD = 10.06, p = .73$). For healthy foods, there was greater increased valuation of trained vs. untrained foods in the active vs. control group immediately post-training (group x food type interaction, $F(1,310) = 4.69, p = .031, \eta_p^2 = .015$; significant difference between food types in the active group $M = 1.35, SD = 6.42, p = .007$, but not in the control group $M = -0.23, SD = 6.42, p = 0.66$). There were no significant group x food type interactions for healthy foods at two weeks post-training or for energy-dense foods immediately post-training.

Food Consumption Frequency

A 2 x 3 mixed ANOVA (between subjects factor: *condition* [active or control], within subjects factor: *food type* [energy-dense, healthy, untrained]) was conducted to see whether changes in food consumption frequency were dependent on food type. Results revealed a significant main effect of food type ($F(1.92, 588.86) = 5.93, p = .003, \eta_p^2 = .02$, with Huynh-

Feldt correction). There was a significant difference between energy-dense foods, which reduced in consumption frequency ($M = -.13$, $SD = .63$) and healthy foods which slightly increased in consumption frequency ($M = .01$, $SD = .72$; $p = .02$). There was also a significant difference between energy-dense foods and untrained foods, which also increased in frequency ($M = .06$, $SD = .75$; $p < .001$), but there was no statistically significant difference between healthy and untrained foods ($p = .42$). There was no main effect of training condition ($F(1, 306) = .44$, $p = .51$, $\eta_p^2 = .001$), and importantly, no interaction between condition and food type ($F(1.92, 588.86) = .89$, $p = .41$, $\eta_p^2 = .003$, with Huynh-Feldt correction).

Task Feedback and Awareness

At the end of the study we gathered feedback and assessed awareness of training condition (see Supplementary Information for full analyses). Only a minority of participants reported that the training (active or control) helped to reduce food intake (7.2%) - most were either 'not sure' (33.9%) or negative (59%). A larger proportion reported that they would recommend it to a friend (20.2%), with 30.9% 'not sure' and 48.9% negative. Ratings were more positive in the active vs. control group but there were no significant differences between training groups (both $\chi^2 s < 3.42$, both $p s > .18$). Importantly, we did find that participants in the control group were significantly better at correctly guessing their training condition (86.5%) than those in the active group, who were at chance (49%; $\chi^2(1) = 48.04$, $p < .001$). We conducted exploratory analyses to investigate whether such awareness of training condition had any influence on outcomes (for timepoints 1-3 in the active condition only, see Supplementary Information for full details). We found evidence to suggest that changes in healthy food liking ($p = .09$), frequency of consumption for energy-dense foods ($p = .04$) and weight change ($p = .04$) were moderated by awareness. However, training effects on our primary outcome of devaluation of energy-dense foods were independent of awareness of condition ($p = .27$).

Discussion

The current study aimed to investigate the effects of go/no-go training on food liking, food consumption frequency and weight loss in a large, predominantly healthy sample. Our methods largely replicated those used by Lawrence et al. (2015b) who studied a smaller, more selective (overweight, disinhibited eating) sample. Participants were randomly assigned to one of two training conditions: active training involved inhibiting responses to energy-dense foods and responding to healthy foods, while control training included non-food stimuli only (50% go, 50% no-go). Relative to the control group, participants in the active group showed evidence for decreased liking of energy-dense foods and increased liking of healthy foods. However, there was no evidence for reliable training effects on changes in food consumption frequency or weight loss. Analyses also suggest that awareness of training condition in active participants may have been associated with greater increases in healthy food liking, and greater decreases in consumption frequency of energy-dense foods and weight. Our results are partially consistent with previous studies examining effects of

inhibition training on eating behaviour; the differences, potential explanations and directions for future investigation are discussed.

The primary outcome in the current study was change in self-reported liking for trained, energy-dense foods at two weeks post-training. Our results revealed that both training groups showed a decrease in liking, both immediately post-training and two weeks later. This devaluation was significantly greater in the active compared to the control group at two weeks post-training, but not following a single training session where devaluation effects were generally smaller (by about 1.5 points on the VAS, ~half the size). Effects of inhibition training on stimulus devaluation have previously been demonstrated for a range of stimuli, including foods (Doallo et al., 2012; Driscoll et al., 2018; Houben, Havermans, et al., 2012; Wessel et al., 2014). Using a very similar methodology to the current study, Lawrence et al. (2015b) found that four sessions of active training resulted in a significant reduction in liking of trained, energy-dense foods, when compared to control training, with very similar effects in the active group to those shown here (a mean reduction of 4.6 [SD=11.35; $d_z=.41$] vs. 5.22 [SD=10.47; $d_z=.5$] here). Devaluation following a single training session has also been reported (Veling et al., 2013a; Chen et al., 2016, 2018a). It is possible that we did not find significant single-session effects here due to methodological differences resulting in reduced sensitivity to detect such short-term effects. Chen et al. (2016, 2018a) used within-subject designs in which go and no-go foods were carefully matched according to personalised pre-training ratings, reducing sources of noise. Furthermore, ratings of food *attractiveness* were made using a 200-point (rather than our 100-point) scale. It is possible that attractiveness ratings are more sensitive to training as they are more strongly dependent on situational variables such as desire to eat and hunger, whereas liking may be a more stable perception of the food item (Rogers & Hardman, 2015).

In the current study, we believe that the stronger devaluation effect of training at two weeks post-intervention is likely due to distributed practice effects, with multiple training sessions spaced over consecutive days allowing for greater learning of stimulus-response associations (Bakkour et al., 2018; and see evidence for stronger learning over all training sessions compared to one session in the Supplementary Information). This is consistent with previous studies that have shown greater effects of training on devaluation for participants who had improved memory of task contingencies (Camp & Lawrence, 2019; Chen et al., 2018a, 2018b). Another explanation could be the increased amount of training prior to the two-week outcome measure, compared to the immediate one; whilst we found no evidence for a ‘dose-response’ effect, our study was not designed to manipulate and test dose. Previous studies have indicated that training effects are independent of the number of stimulus pairings within a single session (Jones et al., 2016), suggesting that the best way to maximise training efficacy may be through increased attentional engagement using shorter sessions spread across multiple days (Aulbach et al., 2021; Bakkour et al., 2018; Chen et al., 2019; Veling et al., 2013a). Indeed, several of our active participants commented that the training should be completed over a greater number of days (“I think that any intervention would have to be repeated more frequently than I did this to have significant impact” [11030, active]; “I think it should be longer as 3 days isn't enough to retrain the habits of a lifetime” [11213, active]),

but one commented that it may need to be more engaging to support this (“It was not incredibly engaging, so if it was something that you are planning on people doing to lose weight, they may stop after a few times” [sic; 11545, active]). Future research could seek to manipulate training dose, length and overnight spacing to determine optimal parameters.

In addition to exploring the devaluation of energy-dense foods, we also investigated whether repeatedly responding to healthy foods would increase subjective liking. Our results revealed an increase in liking for healthy foods in the active group only; evidence for this group effect was strongest immediately post-training and was borderline-significant after two weeks. These results are consistent with recent studies that have demonstrated increased ratings of attractiveness following go-training (Chen et al., 2016, 2018a, 2018b); however, effects appear to be subject to methodological variations. Previous studies with positive findings have tended to include go cues in the training protocol, which are believed to increase attention towards these foods (Schonberg et al., 2014; Zoltak et al., 2018; but see Zoltak, Holland, Kukken, & Veling, 2020). Furthermore, participants have rated go foods as more attractive than *untrained* foods, but only when go trials were presented frequently (75% of trials) or when the training encouraged rapid responding (using a staircase procedure to delay the cue onset). When Chen et al. (2016) included a training task with 50% go trials, as in the current study, there was no difference in ratings between go foods and untrained foods. Similarly, Lawrence et al. (2015b), found no effects of (go) training on increased liking ratings when training included an equal number of go and no-go trials. Observed effects may be dependent on increased attention or motivational salience of ‘go’ foods (see Camp & Lawrence, 2019, and discussion about awareness effects below). Research also suggests that the mechanisms involved in increased evaluation of go foods and decreased evaluation of no-go foods differ. Previous studies have found greater go evaluation effects when such trials are frequent, compared to no-go devaluation effects which show the reverse pattern (Chen et al., 2016). Our results also indicate that go effects may be stronger immediately post-training, whereas no-go effects may take longer to develop. A more thorough investigation of long-term training effects on both positive and negative changes in subjective value ratings would be useful.

Our training task used ‘meaningful categories’ with go-training to healthy foods and no-go training to less-healthy (energy-dense) foods (Serfas et al., 2017), making it hard to separate out training and food-category effects. However, exploratory analyses comparing changes in liking for trained and untrained foods within each category suggested that these changes were due to the trained responses rather than category. These analyses also suggested limited generalisation of training effects to the untrained foods in this study, which may be partly due to the limited similarity between trained and untrained foods (e.g. energy-dense snacks in the trained vs. medium energy-density meals in the untrained category).

In addition to measures of subjective food liking we also explored whether effects of training translated into changes in frequency of consumption and weight loss. We found no reliable evidence of training effects for either of these outcome measures; a finding which is only partially consistent with those of Lawrence et al. (2015b). Similar to the present study,

Lawrence et al. found that although both training groups showed a reduction in consumption frequency, there was no group effect, either at one month or six months follow-up (see also Veling et al., 2014). Current and past findings therefore suggest that food frequency measures may detect more general intervention effects, such as increased self-awareness or self-monitoring resulting from taking part in the study and completing the questionnaires. For example, several participants in the control condition referred to general intervention effects ("Even though I think I was in the control condition, I noticed that I was trying to stop myself from snacking." [sic; 11262, control]; "It was interesting to take part in this training, though I was waiting for any more effective result. but it made me think of the food I eat." [sic; 11382, control]). However, it is important to note that food frequency measures in the current study had a limitation - there was an (unintentional) two-week overlap between our pre- and post-measures (i.e. because participants were asked to report their food consumption over the past month the two weeks immediately preceding the start of training were included in both the pre- and 2 weeks post-training outcome measures), which likely reduced sensitivity to detect changes. However, in the future, researchers may want to employ more sensitive measures of food consumption such as 24-hour food diaries, which Lawrence et al. (2015b) did find to be sensitive to detect training effects.

Lawrence et al. (2015b) also found significant effects of training on weight loss. In the current study we found that although the active group lost more weight than the control group, this difference was not statistically significant. Within-subjects effects suggested less weight loss in the current active group ($M = -0.47$ kg, $SD = 2.03$; $d_z = .23$), compared to in Lawrence et al. ($M = -0.67$ kg, $SD = 1.71$; $d_z = .43$), and effects for the control groups were in opposite directions (slight weight loss here [$d_z = .13$] vs. slight weight gain in Lawrence et al. [$d_z = .14$]). Without a more sensitive food diary measure, it is difficult to determine whether or not our training affected eating behaviour; however, these results suggest that any changes that did occur were not sufficient to produce significant group differences in weight loss. One potential explanation for the difference across studies is the different samples involved. The current study mainly recruited healthy-weight psychology students (73% had a BMI within the healthy range, with $M = 23.67$, $SD = 4.29$) who participated for course credit, whereas Lawrence et al. selectively recruited an overweight/obese community sample (78% had a BMI in the overweight and obese range, with $M = 28.9$, $SD = 5.05$) who received no incentive. Participants in the current sample also reported less frequent snacking at baseline, eating each no-go food ~ once/week vs. ~2-4 times/week in Lawrence et al. Training effects on food devaluation/inhibition would be less likely to translate into significant weight-loss in infrequent, compared to more frequent snackers (Veling et al., 2013a). Veling et al. (2014) found that active go/no-go training was only effective, compared to control training, for those with a high BMI (+1 SD; BMI~28). It is possible therefore that we did not see differences in weight loss in the current study due to the already 'healthy' weight and eating behaviour of most of our participants, and their potential lack of motivation to lose weight or their reduced scope to do so (i.e. floor effects). Indeed, several participants made comments along these lines ("I don't snack and I am very disciplined relating to food intake so I was probably not a good candidate for this study." [11348, active]; "I eat very healthy anyway and was in a process of trying to increase my intake of calories, which may have affected my results."

[sic; 11106, active]). We note that another recent trial of food go/no-go training has also shown significant devaluation of trained no-go foods but no significant weight loss in a predominantly young, healthy-weight sample (Najberg et al., 2021). Future studies interested in investigating effects of cognitive control interventions on weight status would benefit from targeting such interventions at those who need them most and are the most motivated to engage with them. More motivated participants should also find the training more acceptable – participants here gave less positive feedback than in Lawrence et al. (where 89% of participants said they would recommend the training to a friend compared to 51% who said they would or might here).

In addition to the recommendations outlined above, we also advise future researchers to thoroughly consider awareness effects. Previous studies on inhibition training have investigated the role of awareness by assessing participants' knowledge of the contingencies between no-go signals and food categories (stimulus-response associations; Adams et al., 2017; Camp & Lawrence, 2019; Chen et al., 2018a, 2018b; Lawrence et al., 2015b). Findings have been mixed, with some studies reporting no effects of awareness on training outcomes while others have shown that increased awareness is associated with greater changes in food liking. In the current study, however, we asked participants to simply guess whether they were in the active or control group. Results revealed that 87% of participants in the control group were aware of their study condition, compared to 49% of active participants. Furthermore, there was evidence to suggest that aware participants in the active group showed greater effects of training on some outcomes, compared to non-aware participants (although not on our primary outcome of devaluation for energy-dense foods). Previous studies have suggested that the moderating role of awareness can be explained by increased attention, which may have a vital role in learning stimulus-response associations and the subsequent effectiveness of cognitive training interventions (Best, Lawrence, Logan, McLaren, & Verbruggen, 2016; Camp & Lawrence, 2019; Chen et al., 2018b; Quandt, Holland, Chen, & Veling, 2019). It has also been suggested that such interventions may benefit from increasing participants' awareness of such contingencies. However, we add a note of caution due to the additional possibility that awareness of training condition may be associated with expectancy effects and demand characteristics. Differences in expected improvement between intervention groups can undermine interpretations of causality by suggesting that positive training effects are due to factors other than the active intervention (i.e. placebo effects; Boot, Simons, Stothart, & Stutts, 2013; Simons et al., 2016). Future studies should therefore investigate awareness effects alongside expectancy effects to allow firm, causal inferences to be drawn.

Conclusion

The results of the present study are only partially consistent with previous findings investigating the effects of inhibition training on subjective liking, eating behaviour and weight loss (Chen et al., 2016, 2018a, 2018b; Lawrence et al., 2015b; Veling et al., 2013b, 2014). Although we were able to replicate some effects on no-go food devaluation, these effects did not translate into reductions in food consumption frequency or weight in this

large, predominantly healthy-weight sample. These findings are consistent with the idea that whilst food-related inhibition training may induce devaluation universally, effects on food intake and weight loss may only be observed in those who overeat, are more overweight and have stronger impulses towards energy-dense foods (Forman et al., 2019; Jones et al., 2016, 2018; Veling et al., 2011, 2013a, 2014). Our findings highlight how differences in study populations and also methodological variations in training and outcome measures may be responsible for differences across studies. We advise future researchers to deliver training in shorter sessions over multiple days, to use more sensitive outcome measures, and to recruit overweight, motivated participants to fully capture training effects. Alongside these recommendations, we encourage future researchers to rule out the possibility that training outcomes are due to differences in outcome expectancy (Boot et al., 2013).

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Contribution Statement

RA, KB, LH, SM, AS, WB, EC, SR, RH, DK, CC, NL contributed to the design and development of the study, LH, SM, AS, WB, EC, SR, RH, DK collected the data, all authors contributed to data processing, analysis and manuscript preparation.

Conflicts of Interest

The authors declare no competing interests.

References

- Adams, R. C., Lawrence, N. S., Verbruggen, F., & Chambers, C. D. (2017). Training response inhibition to reduce food consumption: Mechanisms, stimulus specificity and appropriate training protocols. *Appetite*, *109*, 11–23. <https://doi.org/10.1016/j.appet.2016.11.014>
- Allom, V., Mullan, B., & Hagger, M. (2016). Does inhibitory control training improve health behaviour? A meta-analysis. *Health Psychology Review*, *10*(2), 168–186. <https://doi.org/10.1080/17437199.2015.1051078>
- Aulbach, M.B., Knittle, K., van Beurden, S.B., Haukkala, A., & Lawrence, N.S. (2021) App-based food Go/No-Go training: User engagement and dietary intake in an opportunistic observational study. *Appetite*, *165*, 105315, <https://doi.org/10.1016/j.appet.2021.105315>
- Bakkour, A., Botvinik-Nezer, R., Cohen, N., Hover, A. M., Poldrack, R. A., & Schonberg, T. (2018). Spacing of cue-approach training leads to better maintenance of behavioral change. *PloS One*, *13*(7), e0201580.
- Batterink, L., Yokum, S., & Stice, E. (2010). Body mass correlates inversely with inhibitory control in response to food among adolescent girls: an fMRI study. *NeuroImage*, *52*(4), 1696–1703. <https://doi.org/10.1016/j.neuroimage.2010.05.059>
- Best, M., Lawrence, N. S., Logan, G. D., McLaren, I. P., & Verbruggen, F. (2016). Should I stop or should I go? The role of associations and expectancies. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(1), 115.
- Boot, W. R., Simons, D. J., Stothart, C., & Stutts, C. (2013). The Pervasive Problem With Placebos in Psychology: Why Active Control Groups Are Not Sufficient to Rule Out Placebo Effects. *Perspectives on Psychological Science*, *8*(4), 445–454. <https://doi.org/10.1177/1745691613491271>
- Bray, G. A., Nielsen, S. J., & Popkin, B. M. (2004). Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. *The American Journal of Clinical Nutrition*, *79*(4), 537–543. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/15051594>
- The British Psychological Society. (2019). Standards for the accreditation of undergraduate, conversion and integrated Masters programmes in psychology. <https://www.bps.org.uk/sites/www.bps.org.uk/files/Accreditation/Undergraduate%20Accreditation%20Handbook%202019.pdf>
- Button, K. S., Chambers, C. D., Lawrence, N., & Munafò, M. R. (2019). Grassroots Training for Reproducible Science: A Consortium-Based Approach to the Empirical Dissertation. *Psychology Learning and Teaching*. <https://doi.org/10.1177/1475725719857659>
- Camp, B., & Lawrence, N. S. (2019). Giving pork the chop: Response inhibition training to reduce meat intake. *Appetite*, *141*, 104315.

- Chalmers, D. K., Bowyer, C. A., & Olenick, N. L. (1990). Problem drinking and obesity: a comparison in personality patterns and life-style. *The International Journal of the Addictions*, 25(7), 803–817. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/2272723>
- Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin*, 25(2), 215-224.
- Chen, Z., Holland, R. W., Quandt, J., Dijksterhuis, A., & Veling, H. (2019). When mere action versus inaction leads to robust preference change. *Journal of Personality and Social Psychology*, 117(4), 721–740. <https://doi.org/10.1037/pspa0000158>
- Chen, Z., Veling, H., de Vries, S. P., Bijvank, B. O., Janssen, I., Dijksterhuis, A., & Holland, R. W. (2018b). Go/no-go training changes food evaluation in both morbidly obese and normal-weight individuals. *Journal of Consulting and Clinical Psychology*, 86(12), 980.
- Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2016). How does not responding to appetitive stimuli cause devaluation: Evaluative conditioning or response inhibition? *Journal of Experimental Psychology: General*, 145(12), 1687–1701. <https://doi.org/10.1037/xge0000236>
- Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2018a). Do impulsive individuals benefit more from food go/no-go training? Testing the role of inhibition capacity in the no-go devaluation effect. *Appetite*, 124, 99–110. <https://doi.org/10.1016/j.appet.2017.04.024>
- Churchill, S., & Jessop, D. C. (2011). Reflective and non-reflective antecedents of health-related behaviour: exploring the relative contributions of impulsivity and implicit self-control to the prediction of dietary behaviour. *British Journal of Health Psychology*, 16(Pt 2), 257–272. <https://doi.org/10.1348/135910710X498688>
- Cummins, S., & Macintyre, S. (2006). Food environments and obesity - Neighbourhood or nation? *International Journal of Epidemiology*, 35(1), 100–104. <https://doi.org/10.1093/ije/dyi276>
- Davis, C., Levitan, R. D., Carter, J., Kaplan, A. S., Reid, C., Curtis, C., ... Kennedy, J. L. (2008). Personality and eating behaviors: a case-control study of binge eating disorder. *The International Journal of Eating Disorders*, 41(3), 243–250. <https://doi.org/10.1002/eat.20499>
- Davis, C., Patte, K., Curtis, C., & Reid, C. (2010). Immediate pleasures and future consequences. A neuropsychological study of binge eating and obesity. *Appetite*, 54(1), 208–213. <https://doi.org/10.1016/j.appet.2009.11.002>
- Dickinson, A., & Balleine, B. (2002). The Role of Learning in the Operation of Motivational Systems. In *Stevens' Handbook of Experimental Psychology*, Hoboken, NJ, USA: John Wiley & Sons, Inc. (doi:10.1002/0471214426.pas0312)
- Dickinson, A., & Dearing, M. F. (1979). Appetitive-aversive interactions and inhibitory processes. In A. Dickinson, & R. A. Boakes (Eds.), *Mechanisms of learning and motivation* (pp. 203–231). Hillsdale (New Jersey): Erlbaum.

- Doallo, S., Raymond, J. E., Shapiro, K. L., Kiss, M., Eimer, M., & Nobre, A. C. (2012). Response inhibition results in the emotional devaluation of faces: neural correlates as revealed by fMRI. *Social Cognitive and Affective Neuroscience*, 7(6), 649–659.
<https://doi.org/10.1093/scan/nsr031>
- Driscoll, R. L., de Launay, K. Q., & Fenske, M. J. (2018). Less approach, more avoidance: Response inhibition has motivational consequences for sexual stimuli that reflect changes in affective value not a lingering global brake on behavior. *Psychonomic Bulletin and Review*, 25(1), 463–471. <https://doi.org/10.3758/s13423-017-1291-y>
- Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, 39(2), 175-191.
- Forman, E. M., Manasse, S. M., Dallal, D. H., Crochiere, R. J., Loyka, C. M., Butryn, M. L., ... & Houben, K. (2019). Computerized neurocognitive training for improving dietary health and facilitating weight loss. *Journal of Behavioral Medicine*, 42(6), 1029-1040.
- Fry, J., & Finley, W. (2007). The prevalence and costs of obesity in the EU. *Proceedings of the Nutrition Society*, 64(03), 359–362. <https://doi.org/10.1079/PNS2005443>
- Gormally, J., Black, S., Daston, S., & Rardin, D. (1982). The assessment of binge eating severity among obese persons. *Addictive Behaviors*, 7(1), 47-55.
- Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, 85(2), 348.
- Guitart-Masip, M., Huys, Q. J., Fuentemilla, L., Dayan, P., Duzel, E., & Dolan, R. J. (2012). Go and no-go learning in reward and punishment: Interactions between affect and effect. *Neuroimage*, 62(1), 154-166.
- Houben, K. (2011). Overcoming the urge to splurge: influencing eating behavior by manipulating inhibitory control. *Journal of Behavior Therapy and Experimental Psychiatry*, 42(3), 384–388.
<https://doi.org/10.1016/j.jbtep.2011.02.008>
- Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite*, 56(2), 345–349. <https://doi.org/10.1016/j.appet.2010.12.017>
- Houben, K., & Jansen, A. (2015). Chocolate equals stop: Chocolate-specific inhibition training reduces chocolate intake and go associations with chocolate. *Appetite*, 87, 318–323.
<https://doi.org/10.1016/j.appet.2015.01.005>
- Houben, K., Havermans, R. C., Nederkoorn, C., & Jansen, A. (2012). Beer à no-go: learning to stop responding to alcohol cues reduces alcohol intake via reduced affective associations rather than increased response inhibition. *Addiction (Abingdon, England)*, 107(7), 1280–1287.
<https://doi.org/10.1111/j.1360-0443.2012.03827.x>

- Houben, K., Nederkoorn, C., & Jansen, A. (2012). Too tempting to resist? Past success at weight control rather than dietary restraint determines exposure-induced disinhibited eating. *Appetite*, *59*(2), 550–555. <https://doi.org/10.1016/j.appet.2012.07.004>
- Houben, K., Nederkoorn, C., & Jansen, A. (2014). Eating on impulse: The relation between overweight and food-specific inhibitory control. *Obesity*, *22*(5), 2013–2015. <https://doi.org/10.1002/oby.20670>
- Jeffery, R. W., & Utter, J. (2003). The changing environment and population obesity in the United States. *Obesity research*, *11*(S10), 12S-22S.
- Jones, A., Di Lemma, L. C. G., Robinson, E., Christiansen, P., Nolan, S., Tudur-Smith, C., & Field, M. (2016). Inhibitory control training for appetitive behaviour change: A meta-analytic investigation of mechanisms of action and moderators of effectiveness. *Appetite*, *97*, 16–28. <https://doi.org/10.1016/j.appet.2015.11.013>
- Jones, A., Hardman, C. A., Lawrence, N., & Field, M. (2018). Cognitive training as a potential treatment for overweight and obesity: A critical review of the evidence. *Appetite*, *124*, 50–67. <https://doi.org/10.1016/j.appet.2017.05.032>
- Konorski, J. (1967). *Integrative activity of the brain: An interdisciplinary approach*. Chicago: University of Chicago Press.
- Lavagnino, L., Arnone, D., Cao, B., Soares, J. C., & Selvaraj, S. (2016). Inhibitory control in obesity and binge eating disorder: A systematic review and meta-analysis of neurocognitive and neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, *68*, 714–726. <https://doi.org/10.1016/j.neubiorev.2016.06.041>
- Lawrence, N. S., Hinton, E. C., Parkinson, J. A., & Lawrence, A. D. (2012). Nucleus accumbens response to food cues predicts subsequent snack consumption in women and increased body mass index in those with reduced self-control. *NeuroImage*, *63*(1), 415–422. <https://doi.org/10.1016/j.neuroimage.2012.06.070>
- Lawrence, N. S., O’Sullivan, J., Parslow, D., Javaid, M., Adams, R. C., Chambers, C. D., ... Verbruggen, F. (2015b). Training response inhibition to food is associated with weight loss and reduced energy intake. *Appetite*, *95*, 17–28. <https://doi.org/10.1016/j.appet.2015.06.009>
- Lawrence, N. S., Verbruggen, F., Morrison, S., Adams, R. C., & Chambers, C. D. (2015a). Stopping to food can reduce intake. Effects of stimulus-specificity and individual differences in dietary restraint. *Appetite*, *85*, 91–103. <https://doi.org/10.1016/j.appet.2014.11.006>
- Leon, A. C., & Heo, M. (2009). Sample sizes required to detect interactions between two binary fixed-effects in a mixed-effects linear regression model. *Computational Statistics & Data Analysis*, *53*(3), 603–608.
- McLaren, I., & Verbruggen, F. (2016). Association, inhibition, and action. In *The Wiley Handbook on the Cognitive Neuroscience of Learning* (pp. 489–514). John Wiley & Sons, Ltd.

- Mokdad, A. H., Ford, E. S., Bowman, B. A., Dietz, W. H., Vinicor, F., Bales, V. S., & Marks, J. S. (2003). Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *JAMA : The Journal of the American Medical Association*, *289*(1), 76–79. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed/12503980>
- Najberg, H., Rigamonto, M., Mouthon, M., & Spierer, L. (2021) Modifying food items valuation and weight with gamified executive control training. *Royal Society Open Science*, *8*, 191288. <https://doi.org/10.1098/rsos.191288>
- Nederkoorn, C., Coelho, J. S., Guerrieri, R., Houben, K., & Jansen, A. (2012). Specificity of the failure to inhibit responses in overweight children. *Appetite*, *59*(2), 409-413.
- Nederkoorn, C., Smulders, F. T. Y., Havermans, R. C., Roefs, A., & Jansen, A. (2006). Impulsivity in obese women. *Appetite*, *47*, 253–256. <https://doi.org/10.1016/j.appet.2006.05.008>
- Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., ... Gakidou, E. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, *384*(9945), 766–781. [https://doi.org/10.1016/S0140-6736\(14\)60460-8](https://doi.org/10.1016/S0140-6736(14)60460-8)
- Oomen, D., Grol, M., Spronk, D., Booth, C., & Fox, E. (2018). Beating uncontrolled eating: Training inhibitory control to reduce food intake and food cue sensitivity. *Appetite*, *131*(August), 73–83. <https://doi.org/10.1016/j.appet.2018.09.007>
- Quandt, J., Holland, R. W., Chen, Z., & Veling, H. (2019). The role of attention in explaining the no-go devaluation effect: Effects on appetitive food items. *Journal of Experimental Psychology: Human Perception and Performance*, *45*(8), 1119.
- Rogers, P. J., & Hardman, C. A. (2015). Food reward. What it is and how to measure it. *Appetite*, *90*, 1–15. <https://doi.org/10.1016/j.appet.2015.02.032>
- Rosenberg, M. (1965). Rosenberg self-esteem scale (RSE). Acceptance and commitment therapy. *Measures Package*, *61*, 52.
- Schonberg, T., Bakkour, A., Hover, A. M., Mumford, J. A., Nagar, L., Perez, J., & Poldrack, R. A. (2014). Changing value through cued approach: An automatic mechanism of behavior change. *Nature Neuroscience*, *17*(4), 625–630. <https://doi.org/10.1038/nn.3673>
- Schwarzer, R., & Jerusalem, M. (1995). Optimistic self-beliefs as a resource factor in coping with stress. In *Extreme Stress and Communities: Impact and Intervention* (pp. 159-177). Springer, Dordrecht.
- Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., & Stine-Morrow, E. A. L. (2016). Do “Brain-Training” Programs Work? *Psychological Science in the Public Interest, Supplement*, *17*(3), 103–186. <https://doi.org/10.1177/1529100616661983>
- Stice, E., Lawrence, N. S., Kemps, E., & Veling, H. (2016). Training motor responses to food: A novel treatment for obesity targeting implicit processes. *Clinical Psychology Review*, *49*, 16–27. <https://doi.org/10.1016/j.cpr.2016.06.005>

- Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, 8(3), 220–247. https://doi.org/10.1207/s15327957pspr0803_1
- Stunkard, A. J., & Messick, S. (1985). The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *Journal of Psychosomatic Research*, 29(1), 71-83.
- Turton, R., Bruidegom, K., Cardi, V., Hirsch, C. R., & Treasure, J. (2016). Novel methods to help develop healthier eating habits for eating and weight disorders: A systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews*, 61, 132–155. <https://doi.org/10.1016/j.neubiorev.2015.12.008>
- van Koningsbruggen, G. M., Veling, H., Stroebe, W., & Aarts, H. (2013). Comparing two psychological interventions in reducing impulsive processes of eating behaviour: Effects on self-selected portion size. *British Journal of Health Psychology*, 1–16. <https://doi.org/10.1111/bjhp.12075>
- Van Strien, T., Frijters, J. E., Bergers, G. P., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders*, 5(2), 295-315.
- Veling, H., Aarts, H., & Papies, E. K. (2011). Using stop signals to inhibit chronic dieters' responses toward palatable foods. *Behaviour Research and Therapy*, 49(11), 771–780. <https://doi.org/10.1016/j.brat.2011.08.005>
- Veling, H., Aarts, H., & Stroebe, W. (2013a). Stop signals decrease choices for palatable foods through decreased food evaluation. *Frontiers in Psychology*, 4(November), 875. <https://doi.org/10.3389/fpsyg.2013.00875>
- Veling, H., Aarts, H., & Stroebe, W. (2013b). Using stop signals to reduce impulsive choices for palatable unhealthy foods. *British Journal of Health Psychology*, 18(2), 354–368. <https://doi.org/10.1111/j.2044-8287.2012.02092.x>
- Veling, H., Chen, Z., Tombrock, M. C., Verpaalen, I. A. M., Schmitz, L. I., Dijksterhuis, A., & Holland, R. W. (2017b). Training impulsive choices for healthy and sustainable food. *Journal of Experimental Psychology: Applied*, 23(2), 204–215. <https://doi.org/10.1037/xap0000112>
- Veling, H., Lawrence, N. S., Chen, Z., van Koningsbruggen, G. M., & Holland, R. W. (2017a). What Is Trained During Food Go/No-Go Training? A Review Focusing on Mechanisms and a Research Agenda. *Current Addiction Reports*, 4(1), 35–41. <https://doi.org/10.1007/s40429-017-0131-5>
- Veling, H., van Koningsbruggen, G. M., Aarts, H., & Stroebe, W. (2014). Targeting impulsive processes of eating behavior via the internet. Effects on body weight. *Appetite*, 78, 102–109. <https://doi.org/10.1016/j.appet.2014.03.014>
- Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences*, 12(11), 418–424. <https://doi.org/10.1016/j.tics.2008.07.005>

- Verbruggen, F., Best, M., Bowditch, W. A., Stevens, T., & McLaren, I. P. L. (2014). The inhibitory control reflex. *Neuropsychologia*, 1–16.
<https://doi.org/10.1016/j.neuropsychologia.2014.08.014>
- Wessel, J. R., O’Doherty, J. P., Berkebile, M. M., Linderman, D., & Aron, A. R. (2014). Stimulus devaluation induced by stopping action. *Journal of Experimental Psychology: General*, Vol. 143, pp. 2316–2329. <https://doi.org/10.1037/xge0000022>
- WHO. (2018). Obesity and Overweight; World Health Organization: Geneva, Switzerland
- Zoltak, M. J., Holland, R. W., Kukken, N., & Veling, H. (2020). Training choices toward low value options. *Judgment & Decision Making*, 15.
- Zoltak, M. J., Veling, H., Chen, Z., & Holland, R. W. (2018). Attention! Can choices for low value food over high value food be trained? *Appetite*, 124, 124–132.
<https://doi.org/10.1016/j.appet.2017.06.010>

Ethics Statement

Ethics Approval

Ethical approval for the study was granted by the Psychology Ethics Committee at the University of Exeter, the School of Psychology Research Ethics Committee at Cardiff University and the Psychology Ethics Committee at the University of Bath.

Approval code: 2017/1364

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Informed Consent

The nature, purpose and risks of the study were explained to participants. The participants received information sheets in advance of the study and were given the opportunity to ask questions. Informed consent was obtained in written form for the laboratory study, and for the online study, participants were asked to show they consented by clicking on a “continue” button.