To go or not to go: A proof of concept study testing food-specific inhibition training for women with eating and weight disorders

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Acknowledgements

Thank you to all of the participants that took part within this study. The authors are also very grateful to Dr. Valeria Mondelli for her help with recruitment at King's College Hospital; Louise Gregor and Dr. Marília Herkenoff Araujo for their support with data entry and Jenni Leppanen for her assistance with data analysis.

Financial support

Robert Turton receives funding from the Medical Research Council (MRC) and the Psychiatry Research Trust (PRT) (Grant PCPTAAR). Dr. Bruno Palazzo Nazar has received funding from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and from the Federal University of Rio de Janeiro (UFRJ). Dr. Emilee Burgess received funding from the University of Alabama at Birmingham and Nova Scotia Health Authority. Dr. Colette Hirsch, Professor Janet Treasure OBE and Dr. Valentina Cardi, receive salary support from the National Institute for Health Research (NIHR), Mental Health Biomedical Research Centre at South London and Maudsley NHS Foundation Trust and King's College London. The views expressed in this article are those of the author(s) and not necessarily those of Kings College London, CAPES, UFRJ, the MRC, PRT, the NIHR or the Department of Health. The authors' declare that they have no conflicts of interest.

Abstract

Inefficient food-specific inhibitory control is a potential mechanism that underlies binge-eating in Bulimia Nervosa (BN) and Binge Eating Disorder (BED). Go/ no-go training tools have been developed to increase inhibitory control over eating impulses. Using a within-subjects design this study examined whether one session of food-specific go/ no-go training, versus general inhibitory control training, modifies eating behaviour. The primary outcome measure was food consumption on a taste test following each training session. Women with BN and BED had small non-significant reductions in high-calorie food consumption on the taste test following the food-specific compared to the general training. There were no effects on eating disorder symptomatic behaviour (i.e., binge-eating/ purging) in the 24 hours post-training. The training task was found to be acceptable by the clinical groups. More research is needed with larger sample sizes to determine the effectiveness of this training approach for clinical populations.

Abstract word count: 145 (Journal limit = 150)

Article word count: 5,516 (Journal limit = 6,000)

Keywords

Eating disorders; Bulimia nervosa; Binge eating disorder; Inhibition training; Habit theory

1. Introduction

Inhibitory control is the ability to override an impulse or stop an initiated action and has been highlighted by the Research Domain Criteria as a 'cognitive system' that might underlie psychopathology across a range of mental illnesses (National Institute of Mental Health, 2016). Indeed, food-specific inhibitory control could be a mechanism that subserves binge-eating episodes in Bulimia Nervosa (BN) and Binge Eating Disorder (BED) (Pearson, Wonderlich, & Smith, 2015; Robbins, Gillan, Smith, de Wit, & Ersche, 2012; Turton, Chami, & Treasure, 2017). In support of this, a meta-analysis (Wu, Hartmann, Skunde, Herzog and Friederich, 2013) found impairments in inhibitory control towards food and eating stimuli in people with BN (moderate effect size: Cohen's d = -.67) and food-specific inhibitory control difficulties have also been reported for people with BED with this difficulty positively correlating with eating disorder psychopathology (Svaldi, Naumann, Trentowska, & Schmitz, 2014). It follows that improving food-specific inhibitory control might reduce binge-eating in BN and BED (Treasure, Cardi, Leppanen, & Turton, 2015).

Novel computerised go/ no-go training approaches have been created in which high-calorie foods always appear onscreen with no-go cues whereas other items (e.g., low-calorie foods/ non-food images) appear with go cues. It is hypothesised that the approach works by reducing automatic motor excitability towards high-calorie foods, increasing top-down inhibitory control and/or through food devaluation (e.g., Chen, Veling, Dijksterhuis, & Holland, 2016; Jones, Hardman, Lawrence, & Field, 2017; Veling, Lawrence, Chen, van Koningsbruggen, & Holland, 2017). Go cues can also

be used to train disinhibition towards target stimuli (e.g., priming people towards alternate food choices; e.g., Blackburne, Rodriquez, & Johnstone, 2016).

Given this, in addition to improving food-specific inhibitory control, food devaluation could also be a helpful outcome of the training for people with eating disorders. This is because women with BN and BED have increased activation in the medial orbitofrontal cortex when receiving food rewards than weight-matched participants, which positively correlates with the tendency to eat in response to external food cues (Simon et al., 2016). High-calorie food cues have also been found to increase state food cravings in women with bulimic-type illnesses (Van den Eynde et al., 2012). These findings suggest that women with BN and BED may have stronger impulses towards these foods and therefore, may have stronger training effects than people without eating disorders.

Experimental studies have found that for restrained eaters a single session of training can reduce high-calorie food consumption in the laboratory (e.g., Adams, Lawrence, Verbruggen, & Chambers, 2017; Houben & Jansen, 2011; Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015b). Furthermore, Veling, Aarts and Papies (2011) reported that restrained eaters consume less no-go trained sweets in the 24 hours post-training, suggesting that the training also has an effect outside of the laboratory. For individuals who are overweight or obese, it has been found to increase low-calorie food consumption and reduce high-calorie food consumption (Blackburne, Rodriquez, & Johnstone, 2016), and to lower daily energy intake and 'liking' ratings of high-calorie foods (Lawrence et al., 2015a).

Meta-analyses of these studies have found that a single session of food go/no-go training produces moderate reductions (ranging from Cohen's *d* = .47 to .58) in eating high-calorie foods (Allom, Mullan, & Hagger, 2016; Jones et al., 2016; Turton, Bruidegom, Cardi, Hirsch, & Treasure, 2016). However, most of these studies were conducted in healthy and overweight individuals, and to date, no research has been published in populations with eating disorders. Given the evidence for impaired food-specific inhibitory control in BN and BED, and the promising results in healthy/ overweight populations, a proof of concept study using a single-session of food go/ no-go training in these patient groups seems warranted.

The aim of this proof of concept study was to compare the effect of a single session of food specific inhibition training with general inhibition training in women with BN and BED, using a within-subjects design. Our main hypothesis was that following the food-specific training participants with BN and BED would reduce their intake of high-calorie foods more than in the general training condition and increase low-calorie food consumption. Also, we investigated if overweight/obese women without eating disorders would follow the same behaviour alongside a lean control group. An exploratory hypothesis was that levels of food craving would predict stronger training effects. It was also speculated that eating disorder symptomatic behaviour (i.e., binge-eating/ purging) might decrease in the 24-hours post-training.

2. Materials and methods

2.1. Design

Participants completed a single session of food-specific inhibition training and a general (non-food) version of the training using a within-subjects design. The order that participants completed the two conditions was counterbalanced, with the sessions scheduled approximately one week apart to minimise carryover effects. Participants received either the food or non-food inhibition training first (using the random number generator function in Microsoft Excel®) using a block randomisation approach.

2.2. Participants

Women with BN (*N*=30) and BED (*N*=19) were recruited from the South London and Maudsley eating disorder service, King's College Hospital (Endocrinology and Bariatric Surgery Clinic) and Vincent Square eating disorder service. Participants were also recruited through B-eat (www.b-eat.co.uk). Overweight/obese without an eating disorder and lean women were recruited through advertisements placed on the King's College London website and by fliers placed around campus. In total, 30 lean women (i.e., with a Body Mass Index (BMI) between 18.5 and 24.9) and 19 women with a BMI over 24.9 were recruited.

Participants were screened over the telephone using the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (SCID-5; American Psychiatric Association, 2013). All diagnoses were discussed with a

psychiatrist specialised in eating disorders (BPN or JT). Inclusion criteria for the eating disorder groups included: adult females, a current diagnosis of BN or BED (DSM-5), no substance abuse, no neurological conditions, and no severe co-morbidity (e.g., schizophrenia). Overweight women and lean comparison women were eligible to take part if they had a BMI over 18.5 and no past or current eating disorder diagnosis. Hampstead NHS Research Ethics Committee granted ethical approval for the study.

2.3. Materials

2.3.1. Questionnaires

Eating Disorders Examination Questionnaire (EDEQ; Fairburn & Beglin, 1994)

This self-report questionnaire measures eating psychopathology over the last 28 days. The EDEQ has been found to have strong psychometric properties (Mond, Hay, Rodgers, Owen & Beumont, 2004; Luce & Crowther, 1999). The Cronbach's alpha in this study for the EDEQ total = .97.

Depression Anxiety Stress Scales (DASS-21; Lovibond & Lovibond, 1995)

The DASS-21 measures levels of depression, anxiety and stress over the previous week. The questionnaire has been found to be a reliable and valid measure (Antony, Bieling, Cox, Enns, & Swinson 1998). The Cronbach's alpha for the DASS total = .95.

Food Cravings Questionnaire-Trait (FCQ-T; Cepeda-Benito, Gleaves, Williams, & Erath, 2000)

This 39-item self-report questionnaire assesses trait food cravings. Based upon a multidimensional conceptualisation of food cravings it has nine subscales. Previous research has found the FCQ-T to have strong test-retest reliability (Cepeda-Benito, Gleaves, Williams, & Erath, 2000) and to be a valid measure in clinical populations with eating disorders (Moreno, Rodríquez, Fernandez, Tamez, & Cepeda-Benito, 2008). The Cronbach's alpha for the FCQ total = .98.

2.3.2. Computer based tasks

Food ratings task

Participants were asked to rate a range of different food images based on how much they 'crave' them (these food items were the same as those in Lawrence et al., 2015a). Responses were measured on 10cm long Visual Analogue Scales (VASs). The food images (18 in total) included nine pictures of high-calorie foods (e.g., 'typical binge foods': chocolate pieces, cake, crisps, biscuits) and nine low-calorie foods (e.g., grapes, rice-cakes, carrot sticks). This food ratings task was a computer-based measure that was programmed using Psychtoolbox (Brainard, 1997) and ran on Matlab (the 64 bit version; Mathworks, 2011). It was adapted from the procedures used by Lawrence et al. (2015a) and Veling, Aarts and Stroebe (2013).

Go/ no-go training task

This computer-based task was also programmed using Psychtoolbox and ran on Matlab, and followed the procedure of Lawrence et al. (2015a). Participants were instructed that a rectangle will appear in the middle of the computer screen and that within this a picture appears either within the left or right hand side of the rectangle. If the picture appeared on the left hand side of the rectangle, participants were instructed to respond by pressing the letter 'C' on the keyboard using the index finger of their left hand. Alternatively if the picture appeared on the right hand side, they had to respond by pressing the letter 'M' using the index finger of their right hand. Importantly, participants were instructed to withhold their response and to not press either key if the outline of the rectangle was 'bold'.

The food-specific inhibition training condition included the same nine pictures of high-calorie foods and nine low-calorie foods that were included in the food ratings task. The high-calorie foods were always paired with the no-go signal (i.e., the line of the rectangle always became bold whenever they were presented onscreen and they were supposed to withhold their response). Please see **figure 1** for an outline of the food go/ no-go training task.

Regarding the general inhibition training condition, the instructions for the task were identical as previously outlined with the only difference being that the 18 food images were replaced with 18 non-food images (i.e., items of furniture, gardening tools and stationery items). The non-food images were taken from an online database (Blechert, Meule, Busch, & Ohla, 2014). For further details regarding the go/ no-go training task procedure please see **supplementary item 1**.

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2.3.3. Primary outcome measure: eating behaviour

Taste test

The primary objective of the taste test was to measure food consumption following the training tasks. This procedure was based upon the protocol of Adams et al. (2017) and Lawrence et al. (2015a). Participants were presented with portions of chocolate pieces, crisps, grapes and rice cakes (see **supplementary item 2** for portion sizes and further details regarding the taste test procedure). Participants were also presented with a novel food item that was not included in the training tasks. This was a novel exemplar of the high-calorie food categories (i.e., cake/ biscuits) presented in the food-specific inhibition training. In session one, participants were given a portion of flapjack pieces, while in session two they were given chocolate cake bites. This method was used to examine whether any effect of the no-go training would generalize to novel exemplars of high-calorie foods.

2.3.4. Secondary outcome measures

VASs: anxiety and hunger ratings

VASs anchored by ‘not at all’ and ‘extremely’ (10cms long), were used to measure participants’ levels of anxiety and hunger at baseline and post-training.

Food diary: eating disorder symptomatic behaviour

Participants completed an online food diary (using; www.surveymonkey.net). This food diary was based upon those used in previous research (i.e., Bingham et al., 1997; Lawrence et al., 2015a). It involved participants recording their food and drink consumption during the past 24-hours. Participants were also asked to indicate, with an asterix, any foods that were associated with a sense of 'loss of control' while eating and to record any purging episodes.

2.3.5. Feedback on the training

To assess the acceptability of the food go/ no-go training task participants were asked for their feedback on it. Participants were asked to rate how much they enjoyed doing the task, the effort involved, how frustrating the task was and how difficult they found it to concentrate (i.e., using a scale ranging from 0 = not at all to 10 = extremely). They were also asked if they would be willing to continue to use the training.

2.4. Procedure

Please see **figure 2** for an overview of the study's design. Demographic and baseline materials were completed through the use of an online survey platform (i.e., www.surveymonkey.net). Participants were instructed to eat something two hours before the start of the first and second session and to then not eat until the time of testing (only drinking water was allowed). The sessions were scheduled between

10am and 7pm with both sessions arranged at a similar time if feasible. They were also asked to complete a food diary at baseline (i.e., 24-hours before the first session).

In both sessions, participants completed the hunger and anxiety VASs and the food ratings task at the start of each session (time point one). After this, participants' completed either the food-specific/ general inhibition training conditions (depending on which they had been randomised to receive in the first session). Following the training, participants completed the VASs again (time point two) and were then taken to a different room within the laboratory for the taste test. In the next session participants completed the other training condition followed by the taste test again. After both sessions participants were asked to record a food diary for the following 24-hours. They were also asked for their feedback on the food go/ no-go training task at the end of the study.

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2.5. Data analysis

Participants were excluded from the data analysis if they had incomplete data due to dropping out of the study following session one (*N* = 3 with BN, 3 lean comparison women, and 1 overweight women) or if they did not follow the training task instructions (N = 2 with BED, 1 overweight and 1 lean women; as indicated by go or no-go error rates over 85%). Following these exclusions, there was a total *N* of

86 across all groups, including, 27 women with BN and 17 with BED, alongside 25 lean comparison women and 17 overweight/ obese women. Because this was a proof of concept study we did not do a power calculation to determine effect and sample size.

Craving scores on the food ratings task were then analysed using mixed effects linear models (bootstrapped at 1000 repetitions) using Stata version 14® (StataCorp, 2015). Due to technical reasons there were some missing food ratings task data (N = 1 participant with BN, 2 with BED, 3 lean comparison women and 1 overweight women). Separate models were run for the high- and low-calorie foods with the predictors of group (i.e., BN, BED, overweight women or lean comparison women) and training condition (i.e., food-specific or general inhibition training). The Benjamini and Hochberg (1995) correction was used because multiple comparisons were performed. Following this, a p value threshold of < .042 was used to signify statistical significance for the food cravings data at baseline.

Error rates for go and no-go trials and reaction times were analysed to examine training fidelity. To analyse the taste test data, a mixed effects linear model (bootstrapped at 1000 repetitions) was also carried out to analyse the amount of calories consumed on the taste test between the two training conditions. The food items presented in the taste test were grouped into food types: '*no-go* trained foods' (i.e., chocolate pieces and crisps), '*go* trained foods' (i.e., grapes and rice cakes) and '*novelty exemplar* foods' (flapjack bites or chocolate cake bites). The total amount consumed (measured in kCals) was calculated for each of these three groups. For the analysis, the predictors included in the model were: group, training condition, and

food type. The amount of calories consumed was the outcome variable. Due to multiple comparisons, a *p* value threshold of < .042 was used when examining group differences in food consumption. As this was a proof of concept study, effect sizes were calculated for each of the food types on the taste test to help aid the development of future studies. Standardised Mean Change (SMC) effect sizes were calculated due to the study's within-subjects design (e.g., Morris & DeShon, 2002).

To examine whether VASs for anxiety and hunger differed at baseline and post-training mixed effects linear models were used. The food diaries were analysed to examine levels of eating disorder symptomatic behaviour (i.e., binge-eating/ purging) in the 24-hours post training to test the effectiveness of the training/ whether it caused any adverse effects.

3. Results

Demographic and clinical characteristics

An overview of participants' demographics and clinical characteristics is presented in **table 1**. As to be expected, participants with BN and BED had significantly greater levels of eating disorder psychopathology, depression, anxiety and stress than the comparison women. Eating disorder symptoms (EDEQ total) and depression, anxiety, and stress (DASS-21 total) did not significantly differ between the women with BN and BED. Thirty-three percent (9/27) of the participants with BN and 35% (6/17) of the participants with BED had a co-morbid diagnosis for either an anxiety or major depressive disorder at the time of the study, as assessed by the SCID-5. Also, four participants with BN and one participant with BED were taking medication for mental health problems (i.e., antidepressants). The participants with BED weighed significantly more than the participants with BN, overweight women and lean comparison women.

The participants with BN and BED had significantly greater craving scores (FCQ-T) compared to both the overweight women and lean comparison women for all subscales, including those related to internal (e.g., negative affect) and external (e.g., resisting food at a buffet) cues. There were no significant differences in participants' levels of anxiety and hunger (as measured by the VASs) at the baseline of both training sessions (all $p > .05$).

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Craving ratings for both high- and low-calorie foods were taken at the baseline of both sessions:

High-calorie food cravings

A 4x2 mixed effects linear model (i.e., group x training condition) showed that there was a significant main effect of group on VAS craving ratings for the high-calorie foods ($X^2(3) = 35.66$, $p < .001$). Pairwise comparisons showed that participants with BN significantly craved these foods ($M = 46.7$, $SD = 24.04$) more than the lean comparison women ($M = 39.12$, $SD = 22.43$; $Z = 2.31$, $p = .021$). The participants with BED craved them significantly more ($M = 62.39$, $SD = 22.5$) than the lean comparison women ($Z = 5.97$, $p < .001$), overweight women ($M = 46.22$, $SD = 17.54$; $Z = 4.04$, $p < .001$) and the participants with BN ($Z = 4.11$, $p < .001$). The overweight women craved them significantly more than the lean comparison women ($Z = 2.31$, $p = .021$). There was no significant difference between the overweight women and the participants with BN ($Z = -.02$, $p = .99$). There was no significant main effect of training condition on VAS ratings for the high-calorie foods or interaction between group and training condition (all $p > .05$). As the craving ratings were completed *before* each training task the lack of effect of training condition is not surprising.

Low-calorie food cravings

A 4x2 mixed effects linear model (i.e., group x training condition) showed that there was a significant main effect of group on VAS craving ratings for the low-calorie food items ($X^2(3) = 24.44$, $p < .001$). Subsequent, pairwise comparisons showed that there was no significant difference in cravings for low-calorie foods between the participants with BN ($M = 32.32$, $SD = 16.7$) and the lean comparison women ($M = 33.13$, $SD = 18.18$; $Z = -.16$, $p = .872$). Participants with BED craved these foods less ($M = 24.88$, $SD = 14.42$) than the lean comparison women ($Z = -2.94$, $p = .003$), overweight women ($M = 38.85$, $SD = 15.95$; $Z = -4.92$, $p < .001$) and the participants with BN ($Z = -2.99$, $p = .003$). The overweight women craved the low-calorie food items more than the participants with BN ($Z = 2.55$, $p = .011$) and the lean weight comparison women ($Z = 2.28$, $p = .022$). There was no significant main effect of training condition or interaction between group and training condition on low-calorie food cravings (all $p > .05$).

3.2. **Go/ no-go training task**

Training fidelity

Overall accuracy scores were high (above 85%) for both go and no-go trials across groups and training conditions. There were no significant differences between the participants with BN, BED, overweight women and lean comparison women, in

respect to their overall no-go or go error scores between the training conditions (all $p > .05$). Please see **supplementary item 3** for further details regarding training fidelity.

3.3. **Primary outcome measure**

Taste test analysis

Group differences in food consumption

A 4x2x3 mixed effects linear model (i.e., group x training condition x food type) showed that there was a significant main effect of group on the total amount of calories consumed on the taste test ($X^2(3) = 42.12$, $p < .001$) [†]. Pairwise comparisons showed that there was no significant difference in total calories consumed between the participants with BN ($M = 98.49$, $SD = 103.52$) and lean comparison women ($M = 112.54$, $SD = 94.04$; $Z = -1.62$, $p = .106$). The overweight women ($M = 149.9$, $SD = 110.56$) and participants with BED ($M = 150.04$, $SD = 123.18$; $Z = -.01$, $p = .991$) did not differ in total calories consumed from each other, whereas, the overweight women consumed significantly more calories in total compared to the lean comparison women ($Z = 3.57$, $p < .001$), and the participants with BN ($Z = 4.86$, $p < .001$). The participants with BED also consumed significantly more calories than the lean comparison women ($Z = 3.99$, $p < .001$) and the participants with BN ($Z = 5.26$, $p < .001$).

The effect of training condition

There was no significant main effect of training condition ($X^2(1) = 1.31$, $p = .252$), interaction between group and training condition ($X^2(3) = 3.05$, $p = .383$) or between group, training condition and food type ($X^2(6) = 4.88$, $p = .559$) on the total amount of calories consumed (Please see **table 2.**). Effect sizes were in the expected direction for the women with eating and weight disorders. Participants with BN, BED and overweight/ obese women ate less of 'no-go trained foods' (SMC effect sizes small; BN = -.22; BED = -.24; and overweight women = -.04) and 'novelty exemplar food' items (SMC effect sizes small; BN = -.23; BED = -.1; and overweight women = -.34) in the food-specific versus general inhibitory control training. They also ate more 'go trained foods' in the food-specific training condition relative to the general inhibitory control training (SMC effect size small; BN = .16; BED = .04; and overweight women = .23). The lean comparison women ate more 'no-go trained foods' in the food-specific versus the general inhibitory control training (SMC effect size small = .18; i.e., the opposite direction to the expected effect).

Exploratory correlations

Food craving ratings for the high calorie foods did not significantly correlate with the difference score for highly palatable (i.e., no-go trained food) food consumption on the taste test between the food-specific and general inhibition training conditions for the women with BN ($r = .019$, $p = .925$), BED ($r = -.088$, $p = .747$), overweight women ($r = -.269$, $p = .146$) or lean comparison women ($r = .268$, $p = .217$).

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3.4. **Secondary outcome measures**

3.4.1. VASs: anxiety and hunger ratings

A 4x2x2 mixed effects linear model (i.e., group x training condition x time point) showed that there was not a significant main effect of condition (p = .15) or time point (p = .28) on participants' anxiety levels. Regarding hunger, there was not a significant main effect of condition (p = .87), although there was a significant main effect for time point ($X^2(1) = 10.87$, p = .001). Pairwise comparisons showed that participants were more hungry post-training (i.e., just before the taste test) than at baseline in both conditions (Z = 3.3, p = .001).

3.4.2. Food diary: eating disorder symptomatic behaviour

Compared to baseline, fewer participants' experienced binge-eating/ purging episodes after both sessions but there were no significant differences between food specific and general inhibitory control training (all $p > .05$) (please see **table S4**).

3.5. **Feedback on the training**

The ratings out of 10 were: enjoyment (*M* = 5.8, *SD* = 1.68), effort (*M* = 5.1, *SD* = 2.43), frustration (*M* = 3.79, *SD* = 2.99) and difficulty in concentrating on the task (*M* = 5.11, *SD* = 2.14). Regarding its acceptability, 92% reported that they would be willing to continue to use the training. Three women with BN didn't return for the second session (i.e., two of these patients had the food-specific inhibition training in session one).

4. Discussion

This study hypothesised that following the food-specific training participants with BN and BED would reduce their intake of high-calorie foods more than in the general training condition and increase low-calorie food consumption. Also, we examined if overweight women would follow the same behaviour alongside a lean control group. The participants with BN and BED had small non-significant reductions in their consumption of no-go trained, high-calorie foods, post food-specific relative to general inhibition training. There was virtually no change in the consumption of the "healthy" go trained foods for participants with eating disorders. A possible explanation for the non-significant effects of training on food consumption could be that the participants with eating disorders had markers of severe illness (long-illness durations), meaning that an increased dose of training may have been needed to produce greater changes in eating behaviour.

Paradoxically, in the lean comparison women, there was a small increase in the consumption of high-calorie food in the food-specific inhibition training condition. This could possibly be due to the exposure to food images in the active training condition priming lean participants to then consume these foods in the taste test, whereas for the overweight and eating disorder groups the training might have had the opposite effect due to it targeting executive dysfunction hypothesised to be involved in the maintenance of these conditions. Further research is needed to investigate this suggestion.

Food craving ratings did not predict stronger training effects in the present study. Nonetheless, it was interesting to note that at baseline participants with BED craved the high calorie foods more and the low calorie foods less, than the overweight, lean and BN groups. This finding gives support to the theory that people with BED are hyper-responsive to high calorie food cues (e.g., Davis, 2013). Also, the finding that food go/ no-go training was acceptable for the eating disorder groups, corroborates a recent study by Giel, Speer, Schag, Leehr and Zipfel (2017), which found that food-specific inhibition training (using an antisaccade paradigm) was acceptable for women with BED (N = 10 in the training condition). This training approach led to significant improvements in inhibitory control towards high-calorie foods whilst both the experimental and control condition significantly reduced binge-eating episodes.

A strength of this study is that it is the first to test the effective ness of food go/ no-go training for women with eating disorders. This is in line with calls for the testing of more precise treatment approaches for these conditions (Turton, Chami, & Treasure, 2017; Voon, 2015). Further, the inclusion of overweight/ obese women and a lean control group allowed for the comparison of food craving ratings and training effects across participant groups. Another strength of this study is that it followed the protocols of Lawrence et al. (2015a) and Veling, van Koningsbruggen, Aarts and Stroebe (2014), by not including any food images in the control condition. This may be considered a more conservative comparison condition than those that include food stimuli or impulsivity priming (e.g., Veling, Aarts, & Stroebe, 2013). In line with this suggestion, Adams et al. (2017) have recently found reduced food consumption on a taste test after food go/ no-go training relative to a go training condition however, no

difference was found with an observe condition (i.e., participants watched no-go training but didn't make any responses).

A potential limitation of this study is that it used a within-subjects design whereas all previously published research has used a between-subjects design (i.e., except for Houben, 2011). There may be complications associated with repeated sessions when measuring eating behaviour. For example, people may eat a similar amount of food in each session due to memory of the prior eating episode (e.g., Higgs, 2002; Higgs, Robinson, & Lee, 2012). This was supported by the high correlations in the intake of each food type in session one and two (please **see supplementary item 5** for details regarding these analyses). These analyses also showed evidence for order effects, with the greater intake of the no-go trained, high calorie foods, in the second session relative to the first, perhaps due to participants increased familiarity of the procedure and food items in accordance with the mere exposure effect (Zajonc, 1968). These effects may reduce sensitivity to detect the training effects on food intake.

Another consideration is that the taste test may not be the most ecologically valid way to measure training effects on eating behaviour. For instance, Lawrence et al. (2015a) did not find reduced food intake in a taste test following food-specific versus general inhibition trained groups (despite observing weight loss and reduced real-world intake as measured by food diaries) – although the taste test was not conducted under laboratory conditions. Therefore, it may be more appropriate for research to assess the effect of food go/ no-go training on other outcomes such as, BMI or eating disorder psychopathology questionnaires. This research would require more prolonged, multi-

session training to be able to assess the far transfer of the effects of the training to these outcomes.

4.1. Future research directions

Future studies that include changes to the design of the study are needed to build upon the findings of this study with larger samples as the present study was a proof of concept study and underpowered. It would also be of benefit for future research to use food valuation (VAS) and inhibition tests directly before and after the training to assess baseline and post-training levels of food value and inhibitory control. This would provide additional information about the potential mechanisms of inhibitory control training (Veling et al., 2017). Furthermore, it would be of interest to test the training for people with both eating disorders and impulse control disorders, who have been found to have elevated levels of impulsivity (Fernández-Aranda et al., 2006, 2008).

4.2. Clinical implications

In order to help foster healthy habit formation and larger effects in future research, it may be beneficial to incorporate the three main components of habit formation: frequent repetition, associated context cues and the use of intermittent rewards (Wood & Neal, 2016). Following these principles, future studies could test the use of more intensive go/ no-go training protocols whereby people complete numerous sessions of training in various contexts (e.g., home/work). For example, longer training protocols have been found to reduce daily energy and palatable food

intake (Lawrence et al., 2015a; Blackburne, Rodriquez, & Johnstone, 2016), and the liking of high-calorie foods in individuals who are overweight or obese (e.g., Lawrence et al., 2015a). Similar multi-session training protocols may help people with eating disorders to develop more adaptive, and break maladaptive, eating habits. The self-report index of habit strength (Verplanken, & Orbell, 2003) could be used as a possible mediator/ moderator of training outcome in future research studies that test this hypothesis.

In regards to the incorporation of contextual cues into the training, future studies could tailor the training to the individual by uploading participant's personal 'trigger' foods for binge-eating into the training task (Juarascio et al., 2015). A recent pilot study in obesity has suggested that individualising the training leads to reduced activation in the brain regions associated with reward in overweight and obese people (Stice et al., 2016; Stice, Yokum, Veling, Kemps, & Lawrence, 2017). Therefore, it may also be beneficial for future research in eating disorders to adopt this approach of personalising the training. This might help to increase the precision and effect of food-specific inhibition training on eating disorder symptoms. Another contextual cue for binge-eating is negative affect (e.g., Cardi, Leppanen, & Treasure, 2015; Zeeck, Stelzer, Linster, Joos, & Hartmann, 2011). To target this cue future studies could train emotion regulation or positive mood induction techniques alongside inhibitory control training (e.g., Cardi, Esposito, Clarke, Schifano, & Treasure, 2015; Claes et al., 2012).

In future studies, intermittent rewards could also be given to participants by giving them feedback on their performance on the task (e.g., reaction times, correct signs for successful inhibition, and incorrect signs for no-go errors). This could take the format

of a serious game (e.g., Boendermaker, Prins, & Wiers, 2015; Fagundo et al., 2013; Fernández-Aranda et al., 2012). This would have the benefit of enabling the approach to become widely accessible as a mobile application or web-based intervention.

4.3. Conclusions

This proof of concept study tested the use of food-specific inhibition training for women with BN and BED, as well as in groups of overweight women and lean comparison women. On the go/ no-go training tasks, participants learned to successfully inhibit their response to both food and general stimuli. For the clinical groups, small non-significant effect sizes were found for the reduction of high-calorie food consumption. The next steps for research in this area could involve building upon this study with larger sample sizes or trialling the use of more sessions and personalised training protocols in real-world contexts for people with eating disorders.

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Figure captions

Figure 1: An outline of the food-specific inhibition training. Participants have to respond to the go trials by pressing a computer key and withhold their response to the no-go trials (as signalled by the 'bold' rectangle around the food item). The high-calorie foods were always no-go trials. In this comparison condition, the no-go signal was paired with the stationery and gardening tool images (i.e., for 100% of these trials).

Figure 2. This flow-chart outlines the procedure of the study. Abbreviations: VASs = Visual Analogue Scales (for anxiety and hunger).

Footnote:

† This analysis was repeated examining the effectiveness of the training for participants who only showed signs of successfully stopping on the food-specific and general inhibitory control training task. In order to do this analysis, participant's data was excluded if their go or no-go error rates were above 3SDs from the mean for the control condition and over 2SDs from the mean in the food-specific condition (following the procedure of Lawrence et al., 2015). Furthermore, outliers were removed from the taste test analysis if participants consumed more than 3SDs from the mean for any of the food types. This analysis replicated the findings of the main analysis by showing that there was not a main effect of training condition ($p = .41$) or interaction between group, training condition and food type ($p = .79$) on the taste test. This was also the case when examining the food items presented in the taste test individually (all $p > .05$).

	Lean CW(*N*=25) Mean (SD)	BN (*N*=27) Mean (SD)	Overweight (*N*=17) Mean (SD)	BED (*N*=17) Mean (SD)	Test value Significance
Age	27.2 (6.68)	26.56 (9.32)	29.94 (7.24)	32.18 (6.7)	F (3,82) = 2.291, p = .084
BMI	21.66 (1.72)	22.21 (2.58)	29.53(6.68)	35.69 (11.26)	F (3,82) = 24.39, p < .001 Lean CW vs. BN, p = 1 Lean CW vs. Overweight, p < .001* Lean CW vs. BED, p < .001* Overweight vs. BED, p = .023* BN vs. BED, p < .001*
Illness duration (years)	N/A	8.4 (7)	N/A	13.13(9.58)	t (40) = -1.820, p = .076
EDEQ total	.73 (.94)	3.46 (1.17)	1.27 (1.07)	3.96 (.87)	F (3,82) = 50.83, p < .001 Lean CW vs. BN, p < .001* Lean CW vs. Overweight, p = .576 Lean CW vs. BED, p < .001 Overweight vs BED, p < .001* BN vs BED, p = .714
DASS total	8.88 (7.28)	47.26 (28.56)	14.82 (14.27)	52.82 (21.42)	F (3, 82) = 26.37, p < .001 Lean CW vs. BN, p <.001 Lean CW vs. Overweight, p = 1

					Lean CW vs. BED, $p < .001$ Overweight vs. BED, $p < .001$ BN vs. BED, $p = 1$
FCQ-T: Planning to consume food	6.32 (3.14)	13.56 (3.51)	6.62 (3.5)	14.06 (3.01)	F (3,81) = 34.65, $p < .001$ Lean CW vs. BN, $p < .001$* Lean CW vs. Overweight, $p = 1$ Lean CW vs. BED, $p < .001$* Overweight vs. BED, $p < .001$* BN vs. BED, $p = 1$
FCQ-T: Positive reinforcement	10.52 (4.5)	17.67 (5.95)	9.19 (5)	18.12 (5.8)	F (3,81) = 15.42, $p < .001$ Lean CW vs. BN, $p < .001$* Lean CW vs. Overweight, $p = 1$ Lean CW vs. BED, $p < .001$* Overweight vs. BED, $p < .001$* BN vs. BED, $p = .1$
FCQ-T: Negative reinforcement	5.2 (2.04)	10.81 (4.83)	5.69 (3.09)	9.7 (3.69)	F (3,81) = 13.79, $p < .001$ Lean CW vs. BN, $p < .001$* Lean CW vs. Overweight, $p = 1$ Lean CW vs. BED, $p = .001$* Overweight vs BED, $p = .013$* BN vs BED, $p = 1$

FCQ-T: Lack of control	9.8 (4.36)	27.59 (7.28)	9.94 (4.25)	28.71 (4.79)	*F* (3,81) = 76.7, *p* < .001 Lean CW vs. BN, *p* < .001* Lean CW vs. Overweight, *p* = 1 Lean CW vs. BED, *p* < .001* Overweight vs. BED, *p* < .001* BN vs. BED, *p* = 1
FCQ-T: Thoughts about food	11.72 (3.81)	29.48 (9.43)	10.81 (4.98)	29.94 (8.43)	*F* (3,81) = 46.06, *p* < .001 Lean CW vs. BN, *p* < .001* Lean CW vs. Overweight, *p* = 1 Lean CW vs. BED, *p* < .001* Overweight vs. BED, *p* < .001* BN vs. BED, *p* = 1
FCQ-T: Hunger	9.88 (3.59)	14.3 (5.02)	9.2 (3.9)	15 (3.45)	*F* (3,81) = 10.25, *p* < .001 Lean CW vs. BN, *p* = .001* Lean CW vs. Overweight, *p* = 1 Lean CW vs. BED, *p* = .001* Overweight vs. BED, *p* = .001* BN vs. BED, *p* = 1
FCQ-T: Emotional craving	7.84 (3.53)	18.37 (6.03)	8.81 (4.41)	19.94 (4.7)	*F* (3,81) = 35.6, *p* < .001 Lean CW vs. BN, *p* < .001* Lean CW vs. Overweight, *p* = 1 Lean CW vs. BED, *p* < .001* Overweight vs. BED, *p* < .001*

					BN vs. BED, $p = 1$
FCQ-T: Environmental cues trigger eating	9.76 (4.14)	17.78 (4.12)	11.19 (5.2)	18.29 (4.12)	F (3,81) = 22.39, $p < .001$ Lean CW vs. BN, $p < .001$* Lean CW vs. Overweight, $p = 1$ Lean CW vs. BED, $p < .001$* Overweight vs. BED, $p < .001$* BN vs. BED, $p = 1$
FCQ-T: Guilt	6.2 (3.23)	14.89 (3.43)	7.44 (4.32)	15.47 (2.76)	F (3,81) = 43, $p < .001$ Lean CW vs. BN, $p < .001$* Lean CW vs. Overweight, $p = 1$ Lean CW vs. BED, $p < .001$* Overweight vs. BED, $p < .001$* BN vs. BED, $p = 1$

Table 1: This table shows the demographic and clinical characteristics of the participants. Abbreviations: CW = Comparison Women; BMI = Body Mass Index; EDEQ = Eating Disorder Examination Questionnaire; DASS = Depression Anxiety Stress Scale. *Post hoc test is significant once multiple comparisons are controlled for through the Bonferroni correction.

Group	Taste test outcome variable	Training condition (kcals consumed)		Effect size: SMC (95% CI)
		Food-specific (active)	General (control)	
		Mean (SD)	Mean (SD)	
Lean comparison women (N = 25)	No-go trained foods	161.58 (130.58)	140.03 (95.81)	.18 (-.21, .58)
	Go trained foods	62.45 (37.79)	64.89 (37.95)	-.1 (-.49, .29)
	Novelty exemplar food	129.95 (94.25)	116.32 (91.2)	.12 (-.27, .51)
Women with BN (N = 27)	No-go trained foods	129.89 (129.46)	153.25 (140.48)	-.22 (-.6, .17)
	Go trained foods	55.54 (43.31)	50.78 (36.98)	.16 (-.22, .54)
	Novelty exemplar food	86.07 (66.15)	115.41 (115.61)	-.23 (-.61, .16)
Overweight/ obese women (N = 17)	No-go trained foods	219.94 (109.01)	225.35 (150.23)	-.04 (-.51, .44)
	Go trained foods	85.4 (32.78)	77.76 (33.36)	.23 (-.25, .71)

	Novelty exemplar food	123.88 (66.18)	167.1 (117.89)	-.34 (-.83, .15)
Women with BED (*N* = 17)	No-go trained foods	243.2 (111.53)	278.38 (140.59)	-.24 (-.72, .24)
	Go trained foods	46.09 (37)	44.77 (26.77)	.04 (-.44, .51)
	Novelty exemplar food	138.92 (76.86)	148.89 (74.09)	-.1 (-.58, .37)
Women with Binge-eating episodes (BN + BED groups combined) (*N* = 44)	No-go trained foods	173.67 (133.7)	201.59 (151.94)	-.23 (-.53, .06)
	Go trained foods	51.89 (40.71)	48.45 (33.2)	.11 (-.18, .41)
	Novelty exemplar food	106.49 (74.31)	128.34 (101.96)	-.19 (-.49, .11)

Table 2: Shows means and Standard Deviations (SD) for food consumption on the taste test between the food-specific and general inhibitory control training conditions. Effect sizes were calculated for the *no-go* trained, *go* trained and *novelty* high calorie exemplar food items for each group. Standardised mean change effect sizes may be interpreted as small (=> .2), moderate (=> .5) and large (=> .8).