***Examining Cognitive Bias Modification interventions for reducing food value and choice: Two pre-registered, online studies.***

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**Abstract**

There is considerable interest in Cognitive Bias Modification (CBM) as a potential treatment for overweight / obesity. Inhibitory Control Training (ICT: also known as motor response training) and Evaluative Conditioning (EC) are two popular paradigms which rely on associatively learned responses (unhealthy food -> inhibition, or unhealthy food-> negative stimulus, respectively) through repeated cue-response contingencies. Both ICT and EC have demonstrated some effectiveness for reducing food intake, value and / or choice, when administered in the laboratory and online. However, studies have been criticised for inconsistencies in design (e.g. use of inadequate control groups) which makes it difficult to draw robust conclusions. In two pre-registered, online studies our aim was to examine active ICT (study 1: N = 170) and EC (study 2: N = 300) in multiple groups where the cue->response contingencies were systematically varied (100%, 75%, 50%, 25%), before examining food-cue valuations and hypothetical food choice. In both studies varying the cue-> response contingencies did not lead to significant changes in food-cue devaluation following training. ICT did not substantially influence hypothetical food choice, whereas there was weak evidence that EC reduced choice for unhealthy foods, compared to a control group with 50% cue-response contingencies. Taken together both studies provide limited evidence for online CBM as a viable psychological treatment – at least through the mechanism of food-cue devaluation or changes in healthy and unhealthy food choice. Future research is needed to investigate the factors that contribute towards successful CBM training to critically evaluate the potential for these strategies within health interventions.

Keywords: cognitive bias modification; food cues; inhibitory control training; evaluative conditioning.

**1. Introduction**

The prevalence of overweight and obesity has increased to pandemic levels over the past 50 years (Blüher, 2019), and is at least partly attributed to an obesogenic environment saturated with unhealthy food-cues which signal high availability of these foods (Sample et al., 2015). Not everybody exposed to the obesogenic environment demonstrates excessive weight gain, therefore a focus on individual differences could lead to the development of effective interventions (Houben et al., 2015). Interventions that aim to reduce the value of unhealthy food- cues and to increase behavioural control, particularly if administered online, may be a fruitful area of research.

Dual process models (Hofmann et al., 2008; Strack & Deutsch, 2004) have informed a variety of psychological interventions, known collectively as Cognitive Bias Modification. These models suggest that individual responses to food-related cues are regulated through the interactive influences of implicit and reflective processes, which subsequently determine food selection and consumption. Implicit processes are fast acting, require minimal conscious effort and are based on previously formed memory associations (unhealthy food -> feelings of pleasure). Reflective processes are slower, cognitively demanding and serve to direct behaviour towards longer term goals (e.g. *‘I will resist unhealthy food now, as I am attempting to lose weight’*). Although alternative explanations for unhealthy food selection exist (e.g., value-based choice model of self-control (Berkman et al., 2017)), research related to dual process models suggests that individuals who make poorer (unhealthy) food choices may possess strong implicit biases for unhealthy food items, in addition to a weaker reflective system which is unable to resist the desire to consume unhealthy foods (Forman et al., 2019; Jones et al., 2018; Nederkoorn et al., 2010). In support of dual process models, Price et al., (2016) discovered that poorer inhibitory control (the ability to inhibit or delay behavioural responses in line with longer-term goals (Houben et al., 2014)) was associated with overeating in response to palatable stimuli. Lower levels of inhibitory control have also been linked to unsuccessful diet attempts (Brockmeyer et al., 2016; Nederkoorn et al., 2007), with research by Spitoni et al., (2017) discovering that individuals with obesity had poorer inhibitory control abilities compared to healthy weight participants.

 Cognitive Bias Modification (CBM) paradigms attempt to target these implicit and / or reflective processes to attenuate or strengthen their influence on subsequent behaviour (Friese et al., 2011). A typical example is Inhibitory Control Training (ICT). In this paradigm, participants learn to repeatedly inhibit a motor behaviour in the presence of unhealthy-food cues (cue->inhibition response contingency), which is thought to reduce preference and approach related behaviours for these foods (potentially through an object evaluation mechanism rather than training individual inhibitory ability (Johannes et al., 2020). As such ICT is also referred to as motor response training, due to the lack of inhibitory control change as a potential mechanism). Cue-specific inhibition training was developed from Behavioural-Stimulus interaction theory (Veling et al., 2008), which hypothesises that inhibiting to positively valenced cues (e.g. palatable foods) creates a response conflict as the typical response would be to approach these cues (assuming strong implicit processes (Kemps & Tiggemann, 2015). To reduce the conflict, negative valence is attached to the previously positively valanced cues, reducing their perceived value (known as *devaluation*). Devaluation of food-related cues following ICT has been observed reliably in a number of studies (e.g., Chen, et al., 2016; van Koningsbruggen et al., 2014), and is hypothesised as the most likely mechanism of ICT (Veling et al., 2017).

Meta-analyses suggest that ICT has a small but robust effect on food choice and intake for healthy weight participants in the lab (Allom et al., 2016; Jones et al., 2016). However, there is considerable variation in effect sizes between individual studies, and not all studies report positive post training outcomes (Adams et al., 2017 (Study 1); Allom & Mullan, 2015 (Study 2); Bongers et al., 2018; Forman et al., 2016; Oomen et al., 2018), and there is wider debate on the existence of a true underlying effect (known as evidential value (Carbine & Larson, 2017)). This may indicate that differences in the designs of existing research could influence training outcomes, raising uncertainty in relation to cue-ICT effectiveness.

While there is evidence to suggest that a single session of ICT can positively influence health behaviours (Allom et al., 2016), the protocols used within cue-ICT itself are relatively inconsistent. There is some variation between studies in terms of the number of times that participants are required to inhibit responses towards target stimuli (cue->inhibition contingency) in experimental conditions, ranging between 87.5% (Adams et al., 2017; Lawrence et al., 2015a) and 100% (Houben & Jansen, 2011, 2015). Meta analytic work (Jones et al., 2016) revealed that ICT effect size is significantly influenced by participant performance during training, with increased inhibition failures linked to smaller ICT effects. Task performance was also positively correlated with cue->inhibition contingency (i.e., participants are more successful at training where cue->inhibition contingencies are higher), which may partially explain the larger effect sizes observed where studies use Go/No-go training (as the cue->inhibition contingencies within these studies are typically closer to 100%) compared to Stop Signal tasks. This raises questions in relation to the role of the training paradigm within ICT research: variations in cue->inhibition contingencies prevent the direct comparison of studies, which makes it difficult to draw overall conclusions related to ICT effectiveness.

A second CBM approach, evaluative conditioning (EC), attempts to modify the valence of stimuli by pairing images of a target stimuli with either positive or negative images. Pairing food-related cues to negative images (cue->response contingency) is thought to influence preference for the original target stimuli, and reduce appeal and preference for these items (Hollands et al., 2011), suggesting a similar underlying mechanism (*devaluation*) to ICT. EC approaches are used as part of various behaviour change campaigns (for example, anti-smoking (Măgurean, Constantin & Sava, 2016)) and have been successfully applied to the context of eating behaviours, with research demonstrating reductions in unhealthy food intake and preference post EC (Bui & Fazio, 2016; Haynes et al., 2015; Hensels & Baines, 2016; Hollands et al., 2011; Shaw et al., 2016). Despite the apparent success of EC strategies, there are some inconsistencies related to the effectiveness of training: recent work has discovered that while there was some evidence to suggest that EC appeared to be effective at reducing explicit preference for alcoholic drinks, there was no significant effect of active EC on explicit attitudes towards healthy or unhealthy foods (Zerhouni et al., 2019). Similarly, Hollands et al (2016) failed to replicate EC effects from an earlier study (Hollands et al, 2011) and research by Wang et al., (2017) discovered that while an EC intervention influenced attitudes towards chocolate (the target stimuli), there was no significant difference between EC and a control group in subsequent chocolate consumption.

Parallel to the literature on Inhibitory Control Training, there is considerable heterogeneity in the design of studies within the literature. The image type paired with the target stimuli varies across studies, with some work using negative health outcome images (Hollands et al., 2011; Hollands & Marteau, 2016) alongside unhealthy foods, while others use images of negative facial expressions (Shaw et al., 2016) or present information in word form (Bui & Fazio; 2016; Haynes et al., 2015). While most EC training studies pair the target stimuli with the negative outcome for all trials where the target is presented, there is variation in the number of critical trials, ranging from 30 trials per target stimuli (Zerhouni et al., 2019) to 100 (Hollands & Marteau, 2016), and it is not clear how many pairings of the target stimuli and negative outcome are optimal for influencing consumption and preference measures. Meta analytic work (Hofmann et al., 2010) suggests that the number of pairings may influence the strength of the training effect, however, to our knowledge, no study to date has investigated the number of critical pairings at which EC training becomes ineffective. The between study variations make it difficult to identify the most effective training paradigm for EC interventions, and raise questions in relation to the overall impact (and potential application) of training.

A further inconsistency that applies to both cue-ICT and EC research relates to the use of (in)appropriate control/comparison groups. To ensure causal inferences can be made, the inclusion of a control/comparison group is required, however the content of these control groups is not consistent and often *suboptimal* (Jones et al, 2018). While some studies use designs where control participants complete a reversed contingency of the experimental task (e.g., instead of inhibiting responses to 100% of target stimuli, participants inhibit to 0% of target stimuli) there is a risk that this strategy results in an inflation of between group differences (as participants are being trained away from target stimuli rather than not being trained as in a traditional control group (Jones et al., 2016; Jones et al., 2018). Where control groups are designed in this way (sometimes unintentionally) participants are being trained towards healthy food items (known as cue-approach training (Schonberg et al., 2014)), therefore changes in choice and preference for healthy foods should also be measured in CBM studies to thoroughly evaluate effectiveness. Studies should also implement a true control group who complete 50% of each trial type (dependent upon the specific CBM technique) to ensure that an appropriate comparison is made (for example, cue-ICT control participants should respond to 50% healthy and 50% unhealthy items during training (Jones et al., 2018)). While some researchers have expressed concerns in relation to this approach (stating that placebo training can behave as an active training group for participants with pre-existing biases (Kakoschke, Kemps, & Tiggemann, 2018)), Kruijt and Carlbring (2018) argue that 50%/50% control groups are not more or less beneficial for individuals who possess pre-existing biases, and therefore function as an appropriate control comparison group.

Therefore, the aim of the current research was to investigate two specific CBM strategies (cue-specific inhibitory control training (cue-ICT) and evaluative conditioning (EC)) to identify the role of cue-inhibition contingencies and critical pairings in training effectiveness. We chose these two paradigms as both have a large evidence base, and are hypothesised to exert effects on choice / intake through devaluation of unhealthy food-related cues. As the current study is the first (to our knowledge) to directly manipulate cue-inhibition contingencies and critical pairings, we aimed to recruit participants with a range of BMIs to allow for direct comparison with previous work examining the mechanisms of these training paradigms (where the mean BMI typically falls within the ‘healthy’ range (e.g., Adams et al., 2017))*.* In study 1 we examined Inhibitory Control Training and in study 2 we examined Evaluative Conditioning. In both studies participants were randomly allocated to one of four conditions (25% vs. 50% vs. 75% vs. 100%, unhealthy-food inhibition/unhealthy-food negative health outcome pairings). Pre/post training we examined subjective value of food (Chen et al., 2018; Lawrence et al., 2015b), and post intervention explicit food choice (Hollands & Marteau, 2016) as our dependent measures. We also included baseline inhibitory control to food-cues as a covariate in both studies: previous work suggests that state inhibitory control has been linked to variations in CBM training outcomes (Haynes et al., 2015) and theoretical models suggest cognitive bias modification approaches should be more effective in those with pre-existing biases (e.g. poor inhibitory control to food cues (Franken & van de Wetering, 2014)).

Both studies were pre-registered and data is freely accessible (Study 1: https://osf.io/kjpq3; Study 2: https://osf.io/zy27u).

**2. Study 1: Inhibitory control training**

We hypothesised that: i) Participants in the highest cue-inhibition contingency group (100%) will show more pronounced food value changes post training compared to those in lower contingency groups (75%, 50% and 25%)), ii) Participants in the highest cue-inhibition contingency group (100%) will show healthier explicit choices compared to those in lower contingency groups (75%, 50% and 25%), iii) Participants with poorer levels of inhibitory control pre training will show greater benefits from food specific cue-ICT.

**2.1. Method**

*2.1.1. Participants*

One hundred and seventy participants aged between 18 and 75 years (*M =* 27.78 ± 12.20) completed an online study. The sample consisted of 88 females (*Mage* = 29.36 ± 13.36) and 82 males (*Mage* = 26.07±10.63), with an average BMI of 24.72 kg/m2 (5.71). Participants were required to be aged 18+ and self-report no history of eating disorders. We had two recruitment strategies; first, we recruited via online advertisements which mainly targeted the local and wider student community (N = 70), second, we recruited using prolific academic (N=100). Individuals recruited via online advertisements were entered into a prize draw (£50), whereas those participating via Prolific Academic received £3 for completing the study. Importantly, participants from the two recruited samples did not significantly differ on measured demographic variables (age and BMI, see supplementary materials). Our a-priori power analysis revealed that a minimum of 128 participants were required (*d* = .30 (Allom et al., 2016), α = .05, 1 − β = 0.80) to detect a within \* between interaction across the experimental conditions, however we were able to over-sample to increase the accuracy of our effect size estimates.

2.1.2. Measures

*2.1.2.1. Baseline Inhibitory Control*

To identify the pre-existing inhibitory control ability of participants, a food specific go/no-go task was completed (Houben & Jansen, 2011). After 10 unrecorded practice trials, participants completed 160 trials. Participants were required to respond as quickly and accurately as possible by pressing the space bar if no border was present around the image (‘go trial’) , and refrain from responding if a blue border was present (‘no-go’) trial. There were 120 (75%) go trials and 40 (25%) no-go trials. Infrequent no-go trials were used to increase inhibition pressure on the task, in line with recommendations (Meule, 2017). If there was no response, images remained on screen for 1500 ms, and trial-by-trial feedback (‘correct’, ‘incorrect’) was provided for 500 ms. Internal reliability for the measure was high as assessed through split-half measures using ‘go’ trial reaction times (*r =* .80, p < .001).

The number of inhibition errors and the median reaction time (RT) for ‘go’ trials were used to determine baseline levels of inhibitory control, with higher scores (for both measures) indicating poorer initial inhibitory ability. Signal detection (*d*) was also calculated, which is a combined score that represents the ability to respond to, and withhold responses to stimuli. This involved subtracting the z-score for the number of incorrect ‘no-go’ trials from the z-score for the number of correct ‘go’ trials, resulting in data from both ‘go’ and ‘no-go’ trials being included (Littman & Takács, 2017).

*2.1.2.2. Food Value*

Food value was measured by presenting participants with images of 10 healthy and 10 unhealthy food items, and asking ‘*How appealing do you find this image?*’ (Chen et al., 2018). For each food type (healthy/unhealthy), images consisted of trained (N = 6; used in the intervention task) and novel (N = 4; not included within intervention task) images, to determine whether training can result in generalisation to novel stimuli (Veling et al., 2017). The number of images rated (per category) is similar to previous work (Lawrence et al., 2015b; Veling et al., 2013a).Participant responses were measured on a visual analogue scale (VAS) ranging from -100 (not at all) to +100 (extremely). A mean score was then calculated for healthy and unhealthy food item appeal (Lawrence et al., 2015b).

*2.1.2.3. Explicit Preference (based on Hollands & Marteau, 2016)*

Explicit preference was assessed through a forced choice task, where participants were presented with images of 8 food items (four sweet (e.g., chocolate) and savoury (e.g., cucumber sticks); four healthy (e.g., apple) and unhealthy options (e.g., crisps/chips)), and prompted to select the two items that they would most like to consume at that moment in time. Participants could select unhealthy food items (scored as 0), or healthy food items (scored as +1), which resulted in a combined score ranging from 0 (two unhealthy choices) to 2 (2 healthy choices).

*2.1.2.4. Inhibitory Control Training task*

Previous work has used stimulus relevant responding (responding to the content of the images) to determine required participant responses in go/no-go training tasks (Teslovich et al., 2014), but due to the unique manipulation of cue-inhibition contingencies within this study, participants were asked to respond to stimulus irrelevant features (e.g. borders surrounding the images), with an image border prompting participants to withhold their response (no-go trial), and no image border indicating a response was required (go trial)). Images of 6 healthy (e.g. fruits, vegetables) and 6 unhealthy (e.g. chocolate, pizza) foods were presented individually in random locations on screen, and participants either responded to their presentation (by pressing the spacebar), or did not respond. Images remained on screen for 1500 ms if no response was made. Participants received feedback on a trial-by-trial basis (‘correct’ or ‘incorrect’) for 250 ms. The task consisted of 200 trials (100 go, 100 no-go), with the number of each type of trial (unhealthy go/unhealthy no-go/healthy go/healthy no-go) determined by condition allocation, and an untimed comfort break provided after 100 trials. Cue-inhibition contingencies varied per experimental condition, with four possible condition allocations (100% (N = 47), 75% (N = 44), 50% (N = 35) or 25% (N = 44)). The percentage for each group represents the proportion of unhealthy images the group were required to inhibit their responses to (for example, the 100% group inhibited responses to 100% of unhealthy food images, and responded to 100% of healthy food images, participants in the 50% group inhibited to 50% unhealthy food images and 50% healthy food images). Split-half reliability analyses demonstrated high levels of internal reliability for this task (*r =* .86, p < .001), and participant engagement was good, with a mean error rate of 2.40% (*SD* = 6.00) for go trials and 2.87% (*SD* = 3.83) for no-go trials (average error of 2.60% (*SD* = 4.26) across go and no-go trials). There were 10 unrecorded practice trials, which consisted of 50% go and 50% no-go trials.

Healthy and unhealthy food images were selected based upon previously conducted pilot work where 30 food images were scored for appeal. Participants were instructed ‘*For the below images, please indicate how unpleasant or pleasant the image is’* and asked to provide their responsesusing individual Likert scales ranging from 1 (unpleasant) to 10 (pleasant). The most highly rated images (for healthy and unhealthy foods) were used within the intervention (see supplementary materials for example images).

*2.1.3. Procedure*

Participants completed all tasks using Inquisit web 5 (Millisecond Software, SA). After providing informed consent, participants completed basic demographic measures (age, sex, height, weight), and then completed the baseline measure of inhibitory control. This was followed by the pre training food value measure, then one of four versions of the go/no-go training task. The food value measure was then completed for a second time, before participants completed the final explicit preference task. Finally, participants completed a funnelled debrief, where they were shown an image of a healthy food item with no border and asked to select what they predicted to be the required response were the image included in a task (either press the spacebar, do not press the spacebar, or unsure). They were then asked to explain in their own words what they believed the true aim of the study to be using a free text box. Finally, participants were thanked and debriefed. Ethical approval for both studies was granted by the University of Liverpool Health and Life Sciences Ethics Committee.

*2.1.4. Statistical Analysis*

Analyses were pre-registered prior to data collection (https://osf.io/kjpq3). To compare food value preferences dependent on condition, 4 (condition: 25% vs 50% vs 75% vs 100% unhealthy food inhibition) x 2 (time: pre training vs post training) Mixed ANCOVAs were conducted for both healthy and unhealthy food value scores, with number of inhibition errors in the baseline task used as the covariate (to adjust for baseline inhibitory ability). The analyses were repeated with median ‘go’ RT as the covariate (as an alternative measure of inhibitory ability). Explicit food preference was analysed using a one way ANCOVA, again, with inhibition errors as the covariate, with a second analysis conducted using median ‘go’ RT as a covariate, in line with previous work (Littman & Takács., 2017; Verbruggen & Logan, 2008). However, we also clarified these effects using Chi-square due to limit variation in the dependent variable (scores of 0 – 2, see supplementary materials). Additional exploratory analyses were also conducted including Bayes factors, signal detection, generalisation and aim awareness (see supplementary materials).

**2.2. Results**

*2.2.1. Hypothesis one (Participants in the highest cue-inhibition contingency group (100%) will show more pronounced food value changes post training compared to those in lower contingency groups (75%, 50% and 25%)) and Hypothesis three (Participants with poorer levels of inhibitory control pre training will show greater benefits from food specific cue-ICT).*

Differences in healthy food value based upon condition were analysed using a 4 (cue-inhibition contingency: 25%, 50%, 75% and 100%) x 2 (time: pre training, post training) ANCOVA, with healthy food VAS scores as the dependent variable, and number of inhibition errors in the standard go/no-go task as the covariate. There was no significant main effect of condition (*F* (3,165) = 0.67, p = .573, ηp2 = .01), or time (*F* (1,165) = 0.13, p = .720, ηp2 = .001), and there was no significant time by condition interaction (*F* (3,165) = 0.73, p=.536, ηp2 = .01). This analysis was repeated using median ‘go’ trial RT as the covariate, and no significant main effects of condition (*F* (3,165) = 0.69, p = .560, ηp2 = .01), time (*F* (1,165) = 0.27, p = .602, ηp2 = .002) or interaction (*F* (3,165) = 0.74, p = .531, ηp2 = .01) were observed.

To assess unhealthy food value changes, the above analysis was repeated, however, unhealthy food VAS scores were used as the dependent variable. The first ANCOVA (with inhibition errors as the covariate) revealed that there were no significant differences in unhealthy VAS scores based on condition (*F* (3,165) = 0.79, p = .502, ηp2 = .01) or time (*F* (1,165) = 0.49, p = .486, ηp2 = .003), and there was no significant interaction between the variables (*F* (3,165) = 1.15, p = .331, ηp2 = .02). When controlling for median ‘go’ trial RT, there was no main effect of condition (*F* (3,165) = 0.97, p = .407, ηp2 = .02), time (*F* (1,165) = 0.22, p = .642, ηp2 = .001), or time by condition interaction (*F* (3,165) = 1.14, p = .336, ηp2 = .02) (see table 1).

Table 1. Descriptive statistics for mean VAS scores for healthy and unhealthy foods, both pre and post training. Scores range from -100 to +100, with higher scores representing higher food value. Values are mean ± SD.

|  |  |  |
| --- | --- | --- |
|  | Healthy food VAS | Unhealthy food VAS |
| Condition | Pre training | Post training | Pre training | Post training |
| 25% Inhibition Unhealthy | 22.09 (27.48) | 22.22 (30.42) | 25.48 (29.11) | 25.69 (30.63) |
| 50% Inhibition Unhealthy | 25.27 (20.47) | 26.26 (21.68) | 15.77 (25.17) | 17.09 (27.60) |
| 75% Inhibition Unhealthy | 29.84 (28.21) | 28.74 (28.47) | 19.79 (31.27) | 17.89 (32.40) |
| 100% Inhibition Unhealthy | 26.71 (27.61) | 29.22 (32.67) | 16.30 (29.68) | 13.06 (36.24) |

*2.2.2. Hypothesis two: Participants in the highest cue-inhibition contingency group (100%) will show healthier explicit choices compared to those in lower contingency groups (75%, 50% and 25%).*

A one way ANCOVA was conducted, with condition as the independent variable (cue-inhibition contingency: 25%, 50%, 75% and 100%), explicit preference score as the dependent variable and number of inhibition errors as the covariate. There were no significant differences in explicit preference choices based upon condition allocation (*F* (3,164) = 0.46, p =. 709, ηp2 =. 01). This was also the case when median ‘go’ trial RT was used as the covariate (*F* (3,164) = 0.42, p =.738, ηp2 = .008) (see table 2).

Table 2. Mean and standard deviation for explicit preference score. Higher scores represent increased healthy choices.

|  |  |
| --- | --- |
| Condition | Mean explicit preference (± SD) |
| 25% Inhibition Unhealthy | 0.91 (0.60) |
| 50% Inhibition Unhealthy | 0.82 (0.63) |
| 75% Inhibition Unhealthy | 1.00 (0.68) |
| 100% Inhibition Unhealthy | 0.94 (0.73) |

*2.2.3. Supplementary materials*

 We conducted a number of supplementary analyses, which we briefly summarise here. First, we generated Bayes factors for our hypothesis tests which were broadly supportive of the Null Hypothesis (BF01s > 5.27). Second, we demonstrated that the effects of ICT did not differ based upon image novelty (trained vs. non-trained images). Third, we categorised 33 participants as being aware of the experimental aims. Removal of these participants did not meaningfully change our results.

**2.3. Interim summary**

Varying the healthy food cue-inhibition contingencies during an online Inhibitory Control Training task did not significantly influence commonly used outcome measures of stimulus value and food choice. These findings raise questions in relation to the effectiveness of ICT delivered online (see also Wiers et al., 2018), when targeting food value or choice.

**3. Study 2: Evaluative Conditioning**

While evidence suggests that EC training can influence food preferences and consumption, there are issues within the research area in relation to research design and the use of suitable control groups, with some inconsistent findings between studies. Many EC studies pair all images of unhealthy foods with negative outcome images, there is no research to identify the point at which training effects begin to appear (or disappear). Similarly to ICT, the majority of EC research is conducted in laboratory settings, therefore the application of EC interventions to real world contexts is relatively understudied. While EC training focuses on the development of associations between target stimuli, previous research has demonstrated that EC training outcomes were moderated by state inhibitory control (Haynes et al., 2015). The aim of the second study is to investigate how the number of critical pairings in EC influences training effectiveness, which will inform future study and intervention design. We hypothesised that: i) Participants who experience unhealthy food images paired with 100% negative images will show greater changes in food value post training compared to those where unhealthy stimuli are paired with fewer negative images (75%, 50% and 25%)), ii) Participants who experience unhealthy food images paired with 100% negative images will make healthier explicit food choices post training compared to those where unhealthy stimuli are paired with fewer negative images (75%, 50% and 25%), iii) Participants with lower levels of inhibitory control pre-study will benefit more from food based evaluative conditioning online training

**3.1. Method**

*3.1.1. Participants*

Three hundred participants aged between 18 and 70 completed an online study (*M* = 32.09. ±10.58). One-hundred and thirty-eight were female (*Mage* = 33.69 ±11.45) and 162 were male (*Mage* = 30.81 ± 9.73). The average BMI across the sample was 24.95 kg/m2 (SD = 5.33). Identically to study one, participants were required to be 18+, and have no history of eating disorders. All participants were recruited via prolific academic, and received £3 for full completion of the study. A-priori power analysis revealed that a minimum of 128 participants were required (*d* = .30, α = .05, 1 − β = 0.80) to detect a within \* between interaction across the experimental conditions, however, similarly to the first study, we over-sampled to increase the accuracy of our inferences. Participants were not permitted to participate in both studies via Prolific Academic

*3.1.2. Measures*

The measures used within study two were identical to those of study one, with the exception of the training task (detailed below).

*3.1.2.1. Evaluative Conditioning Task*

Participants were presented with pairs of images consisting of a healthy or unhealthy food item, followed by a positive or negative health outcome. Image pairs were either congruent (healthy foods paired with positive health outcomes, unhealthy foods paired with negative health outcomes) or incongruent (healthy foods paired with negative health outcomes, unhealthy foods paired with positive health outcomes), with the number of each trial type varying based upon condition. To ensure participants were engaged with the task, they were asked to respond to the spatial location of stimuli on screen using the ‘E’ (for images presented to the left) and ‘I’ (for images presented to the left) keys (both images were presented on the same side of the screen). The task consisted of 200 trials (100 healthy food images, 100 unhealthy food images). Each image within the pair was presented for a minimum of 1000ms, with the second image remaining on screen until a response was provided. Participants were provided with feedback after each trial (‘correct’ or ‘incorrect’ displayed on screen for 250ms) and also completed 10 unrecorded practice trials prior to training (50% congruent, 50% incongruent).

The number of congruent and incongruent trials presented varied dependent upon experimental condition, with four possible allocations (100%, N = 157[[1]](#footnote-1), 75% N = 45, 50% N = 49, 25% N = 49). The percentage for each group represents the percentage of congruent trials presented to participants (for example, the 100% group were presented with only congruent trials). Split-half reliability analyses (using reaction times) demonstrated high levels of internal reliability for the task (*r =* .75, p < .001).

Food images used in the task were identical to those in study one, and positive (e.g., healthy weight individual) and negative (e.g., individual with obesity) health outcomes were selected from pilot work where 30 positive and negative health images were scored for appeal. Participants were instructed ‘*For the below images, please indicate how unpleasant or pleasant the image is’* and asked to provide their responsesusing individual Likert scales ranging from 1 (unpleasant) to 10 (pleasant). For positive health outcomes, the most highly rated images were used within the intervention, whereas for negative health outcomes, the lowest rated images were used (i.e., the least appealing).

*3.1.2.2. Baseline Inhibitory Control*

Split-half reliability analyses (as calculated using task reaction time) demonstrated high levels of internal reliability (*r =* .81, p < .001) for this task within the second study.

*3.1.3. Procedure*

The procedure mirrored that of study one; however, instead of the go/no-go training task, participants completed the evaluative conditioning task (at the same point in the study). There was also a slight change to the debrief task, as participants were shown an image of a healthy food item and asked which type of image would follow were this a trial in the task (positive health outcome, negative health outcome, or unsure). They were then asked to explain in their own words what they believed the true aim of the study to be using a free text box.

*3.1.4. Statistical Analysis*

Analyses were identical to those of study one, and were pre-registered prior to data collection (https://osf.io/zy27u). Two participants were removed from the final analysis due to non-engagement with the baseline inhibitory control measure (100% error rate for ‘go’ trials).

**3.2. Results**

*3.2.1. Hypothesis one (Participants who experience unhealthy food images paired with 100% negative images will show greater changes in food value post training compared to those where unhealthy stimuli are paired with fewer negative images (75%, 50% and 25%)) and Hypothesis three (Participants with lower levels of inhibitory control pre-study will benefit more from food based evaluative conditioning online training).*

Differences in healthy food value based on condition were analysed using a 4 (congruent trials: 100%, 75%, 50% and 25%) x 2 (time: pre training, post training) ANCOVA, with healthy food VAS as the dependent variable, and number of baseline inhibition errors as the covariate. There was a weak significant main effect of condition (*F* (3, 292) = 2.72, p =.045, ηp2 = .03), with post hoc tests revealing participants in the 100% condition rated healthy foods higher overall (*M* = 42.68, *SE* = 1.72) compared to participants in the 25% group (*M* = 32.56, *SE* = 3.19) (p = .033). Despite this, there were no significant main effects of time (*F* (1, 292) = 0.77, p =.380, ηp2 = .003), and importantly, no significant interaction between condition and time (*F* (3,292) = 0.74, p= .530, ηp2 =.01). The above analysis was repeated using median ‘go’ RT as the covariate, and while the main effect of condition was again significant (*F* (3, 292) = 2.90, p = .035, ηp2 =.03), the main effect of time (*F* (1,292) <.001, p= .998, ηp2 <.001) and the condition by time interaction (*F* (3,292) = 0.75, p= .524, ηp2 = .01) were not.

The above analyses were repeated using unhealthy food VAS as the DV. With number of inhibition errors as the covariate, there was a main effect of condition (*F* (3,292) = 2.80, p = .040, ηp2 = .03), however, post hoc analyses revealed no significant differences between groups (p>.05 in all cases). There was no significant main effect of time (*F* (1,292) = 3.60, p = .059, ηp2 = .01) and no significant condition by time interaction (*F* (3,292) = 0.61, p = .608, ηp2 = .01). When the analysis was repeated using median ‘go’ RT as the covariate, the results were identical, with a main effect of condition (*F* (3,292) = 2.74, p= .044, ηp2 = .03), no main effect of time (*F* (1,292) = 0.86, p= .356, ηp2 <.001) and no condition by time interaction (*F* (3,292) = 0.53, *p* = .662, ηp2 = .01) (see table 3).

Table 3. Descriptive statistics for mean VAS scores for healthy and unhealthy foods, both pre and post training. Scores range from -100 to +100, with higher scores representing higher food value. Values are mean ± SD.

|  |  |  |
| --- | --- | --- |
|  | Healthy food VAS | Unhealthy food VAS |
| Condition | Pre training | Post training | Pre training | Post training |
| 25% Congruent Trials | 31.20 (31.13) | 33.95 (26.10) | 23.51 (31.29) | 21.21 (34.41) |
| 50% Congruent Trials | 39.31 (23.21) | 38.69 (27.65) | 28.48 (32.84) | 22.87 (40.66) |
| 75% Congruent Trials | 37.43 (27.52) | 40.15 (28.13) | 24.60 (38.34) | 20.37 (33.48) |
| 100% Congruent Trials | 38.72 (30.74) | 46.60 (29.31) | 20.22 (32.85) | 9.28 (37.10) |

*3.2.2. Hypothesis two (Participants who experience unhealthy food images paired with 100% negative images will make healthier explicit food choices post training compared to those where unhealthy stimuli are paired with fewer negative images (75%, 50% and 25%))*

A one way ANCOVA was conducted, with condition (congruent trials: 100%, 75%, 50% and 25%) as the independent variable, explicit preference score as the dependent variable and number of inhibition errors as the covariate. The analysis showed a significant effect of condition (*F* (3,289) = 4.16, p = .007, ηp2 = .04), with post-hoc tests revealing a significant difference between the 100% and 50% groups, with the 100% group making healthier choices than the 50% group (p= .026). This was also the case where median ‘go’ RT was used as the covariate (*F* (3,289) = 4.49, p = .004, ηp2 =.05) with the 100% group making healthier choices than the 50% group (p = .020) (see table 4).

Table 4. Mean and standard deviation for explicit preference score. Higher scores represent increased healthy choices

|  |  |
| --- | --- |
| Condition | Mean explicit preference (± SD) |
| 25% Congruent Trials | 1.07 (0.70) |
| 50% Congruent Trials | 0.98 (0.73) |
| 75% Congruent Trials | 1.02 (0.67) |
| 100% Congruent Trials | 1.29 (0.64) |

*3.2.3. Supplementary analyses*

 Similarly, to the first analysis, several supplementary analyses were conducted, which we briefly summarise here. Bayes factors were calculated for our hypothesis tests, and provided strong support for the Null Hypotheses on devaluation (BF01s > 51.93), and weak evidence for the effect on food choice (BF01s ~ 1.16) Secondly, the analyses revealed that there were no effects of generalisation, with no differences in preference between novel and trained images. Finally, 70 participants were able to successfully identify the experimental aims, yet removal of these participants did not meaningfully change the outcome of the analyses.

**4. Discussion**

Across two pre-registered studies, we investigated online CBM training techniques (Inhibitory Control training and Evaluative Conditioning) to identify the most effective training protocols for interventions designed to reduce unhealthy eating behaviours. We attempted to overcome limitations of previous research by; comparing interventions to adequate control groups, examining changes in both healthy/unhealthy food-related outcomes, and adjusting for pre-existing biases (inhibitory control to food-cues) in our models. In Study 1, it was revealed that cue-ICT training did not significantly influence healthy or unhealthy food preferences, and did not influence explicit food choices in a forced choice task. The results from Study 2 showed that while EC training did not appear to significantly influence healthy or unhealthy food preferences, participants who were in the 100% training group (all unhealthy food images paired with negative health outcome images, all healthy food images paired with positive health outcome images) made healthier explicit food choices compared to those in the 50% training group (control group), with no other between groups differences found.

It was hypothesised that when participating in cue-ICT or EC training with cue-inhibition contingencies or critical pairings of 100% (i.e., inhibit to 100% unhealthy food images or experience 100% of unhealthy foods paired with negative health outcome images), participants would show greater changes in food value ratings for healthy and unhealthy foods compared to lower percentage groups. It was also hypothesised that individuals with poorer levels of pre-existing inhibitory control would show greater benefits from training participation (Franken & van de Wetering, 2015; Haynes et al., 2015; Price et al., 2015). The results demonstrated that there were no significant differences in food value ratings as a result of training participation, irrespective of training type (cue-ICT or EC), percentage of cue-inhibitions / critical pairings used, or baseline inhibitory control to food-cues. While cue-ICT and EC task design has not been independently investigated prior to this study, research has demonstrated that both lab based and online cue-ICT and EC can significantly influence food preferences, with CBM training linked to decreased evaluations for targeted food items (Hensels & Baines, 2016; Hollands et al., 2016; Veling et al., 2013a). Previous work has highlighted the positive association between task performance and training effectiveness, with increased performance more likely at higher cue-inhibition percentages (Jones et al., 2016) which suggests that participants in the 100% percentage groups ought to have exhibited pronounced changes to food value (at least in comparison to the 50% control groups) in addition to a linear decrease in effectiveness across the additional percentage conditions (75%, 25%) as expected responses became less predictable (making the development of cue-inhibition associations more difficult) (Verbruggen & Logan, 2008). This raises questions in relation to the impact of the training component within CBM interventions: inferential Bayesian analyses performed within this study provided evidence in support of the null hypothesis, and while work by Oomen et al., (2018) revealed reductions in snack consumption post cue-ICT, there were no changes to food cue sensitivity (as may be expected in line with the devaluation hypothesis (Veling et al., 2017)).

It was also hypothesised that training participation would influence explicit food choices, with higher cue-inhibition / critical pairing percentages (100%) resulting in healthier food choices. While cue-ICT did not significantly influence explicit food selection, participants who completed the 100% version of EC training made healthier explicit choices when compared to participants in the 50% condition. This supports work conducted by Hollands et al., (2011) who also found that a single session of EC led to increased healthy choices in a forced choice task, however, the lack of significant findings for cue-ICT contrasts with previous work, where active training has been associated with increased healthy food selection (Veling, Aarts & Stroebe., 2013b) (particularly where participants are required to make decisions under time pressures (Chen et al., 2019; Chen et al., 2020)).

Utilising an online platform to deliver training allowed for the large-scale recruitment of a diverse participant group, which overcomes previous limitations of convenience samples (mainly psychology students: Jones et al, 2018). Furthermore, the design of the studies ensured that appropriate comparisons were made between active and control groups to determine the true impact of training while also allowing within participant changes to be assessed. Despite this, the online nature of the studies (and the associated variety of contexts in which participants may have completed the tasks) may have influenced completion of, and engagement with the measures. The use of online preference measures also raises issues in relation to validity, as there are no real-world consequences for participants based upon their food choices during the study (Hollands & Marteau, 2016), which may influence participant responses (i.e., making a healthy choice as they will not have to actually consume the food selected). Field et al., (2020) suggests that although many studies measure various proxies of appetitive behaviour, these measures do not always result in robust behavioural changes that would be desirable in an intervention context. The extent to which forced choice tasks are associated with real world food consumption (and subsequently, weight status) is relatively understudied (despite the prevalence of related measures throughout the literature), therefore, these results should be interpreted with caution. Similarly, Wiers et al., (2018) suggests that the lack of control observed within online CBM studies results in less effective bias changes (and subsequently reduced behavioural change), however, work by Kakoschke et al., (2018) found healthy food choices improved after the use of a smartphone app to deliver multiple sessions of ICT training. This mixed evidence may be related to the specific training paradigms, as research suggests that CBM training delivered over multiple sessions is highly effective (Lawrence et al., 2015b).

There are further issues which may complicate the interpretation of our ‘null findings’. Whilst all participants completed the baseline inhibitory control measure prior to training (regardless of condition allocation), engagement with a similar task (with inconsistent food -> inhibition pairings) prior to training may have influenced training outcomes, despite the inclusion of the food value measurement between tasks.Additionally, while the participant group was more representative of the typical population in comparison to previous work, the average participant BMI fell just within the healthy range. Individuals with overweight and obesity may respond differently to CBM training (due to differences in inhibitory ability towards food stimuli (Spitoni et al., 2017)), and future research should examine the impact of CBM training within this specific population. Finally, it is also suggested that personalising task stimuli (i.e., allowing participants to select liked and disliked food items prior to task completion) can lead to more pronounced responses to training (Veling et al., 2013b). Given these issues (a lack of control over personalised stimuli and time pressured responding, and the inclusion of baseline measures of inhibitory control), it is possible that the training effects in this study were weak, and we were not able to reliably detect them based on our sample size (given consistent findings elsewhere (Chen et al, 2019; 2020)). Furthermore, although EC demonstrated weak effects on food choice, caution should be taken when directly comparing ICT and EC here given we were powered to detect much smaller EC effects due to over sampling.

A final methodological issue relates to participant awareness: recent work (Zerhouni et al., 2019) revealed that contingency aware participants (able to recall the type of image (positive, negative or neutral) following a food stimuli item) rated healthy food items more positively after completing a training task. Both cue-ICT and EC are relatively simple tasks in terms of their presentation, and it may be that participants are able to identify stimuli presentation patterns to determine the experimental aims, particularly where inhibition cues and critical pairings are consistent (such as the 100% groups). While in the current study excluding participants aware of the aims did not appear to influence the results, it would be interesting to investigate how participant beliefs in relation to training effectiveness may influence training outcomes.

As such, future research should investigate the effectiveness of repeated online (longitudinal) CBM training and personalisation of task images. Research into potential moderators of the effects of CBM interventions, such as participant awareness, and emotional or restrained eating (e.g. Lawrence et al, 2015) should also be undertaken, to determine if some individuals might benefit more than others. Taken together, this would determine whether multiple (tailored) CBM online training sessions targeted to specific individuals’ are required to effectively elicit behavioural changes, and would also allow for longer term behavioural measures (e.g., weight change) to be monitored to further assess training effectiveness.

In conclusion, two pre-registered studies investigated CBM training strategies (cue-ICT and EC) to identify the role of cue inhibition contingencies and critical pairings in training outcomes. The results revealed that online cue-ICT and EC training did not influence food value (for healthy or unhealthy foods) at any percentage cue inhibition or critical pairing, and only EC training influenced explicit choices, with healthier choices observed when participants completed the 100% version of training (i.e., all unhealthy foods followed by negative health outcome images) compared to control training. These findings raise further questions in relation to the effectiveness of CBM based training strategies in line with recent pre-registered studies (Jones et al., 2020) and meta-analyses (Cristea et al., 2016) in similar fields. Future research should investigate variations that exist between studies to attempt to explain inconsistencies observed throughout the literature and to determine whether CBM approaches have potential as theoretically driven psychological interventions for overweight and obesity.

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1. Due to an error in our online randomisation we considerably over-sampled for the 100% contingency condition. [↑](#footnote-ref-1)