Masterton, S, Hardman, CA and Jones, A

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'Don't stop believing': The role of training beliefs in cognitive bias modification paradigms

Sarah Masterton [*], Charlotte A. Hardman, Andrew Jones

Department of Psychology, University of Liverpool, United Kingdom

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ABSTRACT

Cognitive Bias Modification (CBM) paradigms have previously been applied to target appetite (craving, hunger) and food intake, and are hypothesised to reduce unhealthy food consumption. However, inconsistencies in relation to training outcomes raise questions regarding the efficacy of CBM as a standalone intervention. Furthermore, individual level factors (such as belief in the intervention efficacy) may influence expectations of behaviour change following training. Across two pre-registered studies, our aim was to investigate how directly manipulating beliefs in relation to training purpose and effectiveness influenced food value and choice across two popular CBM paradigms (Inhibitory Control Training (ICT: Study 1) and Evaluative Conditioning (EC: Study 2)). In online studies, participants were presented with a paragraph describing the CBM technique positively (or an unrelated control message) prior to completing either active or control CBM training. Across both studies, the results revealed that active CBM training resulted in a reduction to unhealthy food value (relative to pre-training), but only when paired with a positive manipulation message. Participants who received a control message displayed no significant changes to food value, even where active CBM training was provided. These results suggest that participant beliefs and expectancies have important consequences for CBM effectiveness. Future research should further investigate these factors within CBM contexts to identify their role within successful behaviour change interventions.

1. Introduction

An unhealthy diet is one of the most important modifiable risk factors for numerous diseases (Danaei et al., 2011; Fransen et al., 2017), with the excess consumption of highly palatable, unhealthy foods linked to the development of overweight and obesity (Barlow et al., 2016). While the obesogenic environment promotes unhealthy food consumption (Chaput et al., 2011) through exposure to high fat, salt and sugar food-cues, there are differences between individuals in relation to their responses to these cues: not all individuals demonstrate excessive weight gain, despite the temptations created by repeated exposure to unhealthy food-cues and easily accessible, energy dense foods (Jansen et al., 2015). Examination of the psychological processes that underlie these individual differences in environmental responses may support the development of interventions designed to reduce unhealthy food intake.

Dual process models (Hofmann et al., 2009; Strack & Deutsch, 2004) suggest that responses to food cues are regulated through conflict between implicit and reflective processes, with behavioural outcomes driven by the relative strength of each system. Implicit processes are based on previously formed associations between food cues and outcomes (e.g., feelings of satisfaction after eating an unhealthy food item). These processes are thought to be relatively automatic, and fast acting. Reflective processes are effortful, require conscious thought, and focus on longer-term goals (e.g., consuming healthy food items to maintain weight despite increased reward from unhealthy foods). Dual process models hypothesise that unhealthy food choices are the result of strong implicit preferences for unhealthy foods combined with a weak reflective system unable to resist the intrinsic rewards associated with unhealthy food consumption (Hofmann et al., 2008; Jones et al., 2018), which may help to explain variations in responses to food cues between individuals.

Previous research has supported the application of these models to eating behaviours: work by Kakoschke et al. (2015) demonstrated that while approach biases (the tendency to attend to and approach specific stimuli) and inhibitory control did not independently predict unhealthy food consumption, participants who had a high approach bias for unhealthy food combined with poor inhibitory control abilities consumed higher amounts of unhealthy snack food. Research by Carbine et al.

* Corresponding author. Eleanor Rathbone Building, Bedford St South, University of Liverpool, L69 7ZA, United Kingdom.
E-mail address: s.masterton@liverpool.ac.uk (S. Masterton).

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(2017) revealed that not responding to high calorie foods required increased recruitment of inhibitory control processes (as measured through N2 amplitudes), and lower levels of inhibitory control have previously been linked with overweight and obesity (Sellaro & Colzato, 2017; Spitoni et al., 2017; Yang et al., 2018).

The investigation of dual process models within food contexts has facilitated the development of cognitive training to reduce unhealthy food consumption, referred to as Cognitive Bias Modification (CBM). CBM attempts to address potential imbalances between implicit and/or reflective processes through the completion of tasks designed to improve self-regulatory capacity or weaken the associations that drive automatic processes (Friese et al., 2011; Jones et al., 2018). Cue-specific Inhibitory Control Training (cue-ICT (also referred to as motor response training)) is a novel CBM paradigm that has been applied to food-related responses: during training, participants are prompted to consistently inhibit responses to unhealthy food cues, which is thought to decrease approach behaviours for unhealthy foods and reduce unhealthy food preference and consumption (e.g., Chen et al., 2018; Lawrence et al., 2015; Veling et al., 2021). The mechanisms through which cue-ICT exerts its effects are debated, however, an object evaluation mechanism (potentially devaluation, where training results in a reduction to hedonic stimuli value) is hypothesised to be the most likely mechanism of action (Johannes et al., 2021; Veling et al., 2017). Previous research suggests that cue-ICT can positively influence food choice, preference and consumption behaviours (Chen et al., 2018; Houben & Jansen, 2011; Jones et al., 2016; Oomen et al., 2018; Veling et al., 2021; Yang et al., 2019), however, these findings are not consistent across all studies utilising cue-ICT paradigms (Adams et al., 2017; Becker et al., 2015; Bongers et al., 2018; Carbine et al., 2021; Masterton et al., 2021), and there are broader concerns in relation to the evidential value of existing studies (see Carbine & Larson, 2019).

Evaluative conditioning (EC) is an alternative CBM approach, where participants are exposed to image pairs consisting of a target stimulus (i.e., unhealthy food cues) and positively or negatively valenced images. Similarly to cue-ICT, it is hypothesised that pairing unhealthy food cues with negative images reduces the appeal and subjective value of these items (devaluation), which decreases subsequent unhealthy food consumption (Hollands et al., 2011). EC paradigms have been applied to various health behaviour contexts (including alcohol (Zerhouni et al., 2018), exercise (Antoniewicz & Brand, 2016) and smoking (Scholten et al., 2019)), and previous work has demonstrated that EC training is linked to reduced unhealthy food choice and decreased preference for unhealthy foods (Bui & Fazio, 2016; Haynes et al., 2015; Hollands et al., 2011). While successful EC holds potential in relation to population level behaviour change interventions (Hollands et al., 2013; Marteau et al., 2012)), not all research has found training to be effective. Work by Lebens et al. (2011), demonstrated that while EC had a positive influence on implicit attitudes towards unhealthy foods, there were no differences in calories purchased from fruit/snacks between groups on a virtual shopping task, and Wang et al. (2017) discovered that while EC appeared to have some influence on both implicit and explicit attitudes towards chocolate, there were no differences in chocolate consumption between an experimental and control group. Additionally, recent work (focusing on the application of EC paradigms) found no significant differences in food choice after exposure to pairings of text or image-based health warning labels and unhealthy snack foods (Asbridge et al., 2021).

Although previous research has investigated the design of CBM tasks to attempt to explain inconsistencies in training effectiveness across the literature (e.g., Masterton et al., 2021; Veling et al., 2021), there has been less focus on the participant level factors that may influence the success of CBM interventions. Evidence suggests that contingency awareness (participants' ability to recognise responses and pairings observed within the CBM manipulation) is associated with increased intervention effectiveness within EC paradigms (Hofmann et al., 2010). Work by Zerhouni et al. (2019) demonstrated that a significant main effect of EC on alcohol was partly dependent on contingency awareness, and contingency awareness was predictive of healthier explicit evaluations for high fat foods (within control group participants). Additionally, work by Kattner (2012) revealed that EC training was most effective where participants were instructed to memorise the specific pairs of images used within training tasks. While contingency awareness is not typically measured within cue-ICT contexts, research has shown that *some* participants (albeit a minority) were correctly able to identify true experimental aims within an ICT training study (Di Lemma & Field, 2017).

Contingency awareness within CBM studies raises important questions in relation to participant expectations and beliefs: if some participants are able to correctly identify experimental aims and target stimuli within a study, this may influence their engagement with (and belief in) training, and consequentially, food preference and choice outcomes. Previous work (Boot et al., 2013) has highlighted the role of participant expectations within the evaluation of psychological interventions: while active training groups can help to match experimental and control groups in terms of experimental demands, participant beliefs in relation to the purpose and benefits of training appear to also influence outcome measures, which, if not accounted for, could undermine conclusions regarding intervention effectiveness. Specifically, previous work investigating the acceptability of CBM as a treatment for anxiety disorders (Beard et al., 2012) highlighted that many participants were sceptical about the potential of training to influence behaviour, and felt that CBM was only useful to them when they understood the purpose of the tasks and the potential benefits of training. Additionally, Rabipour and Davidson (2015) investigated how beliefs about cognitive 'training' tasks related to perceived effectiveness, and found that a positive manipulation message increased participant expectations for training (although the subsequent impact on behaviour was not measured). These findings suggest that participant beliefs and understanding of training have implications for engagement with (and expectations for) training: to our knowledge, no study to date has investigated how participant beliefs in relation to CBM (within a food context) can directly influence intervention success.

Therefore, the aim of the current research was to investigate how directly manipulating participant beliefs regarding the efficacy of two CBM approaches (cue-specific inhibitory control training and evaluative conditioning) influenced training outcomes. As previous research has demonstrated that design differences (in relation to cue-inhibition contingencies/critical pairings) for these two specific CBM strategies do not significantly influence training outcomes (Masterton et al., 2021), we focused on 100% contingencies (unhealthy food – inhibition/negative outcome image) for active training, and 50% contingencies for control training to avoid inflating between group differences (Jones et al., 2018). Subjective food value (Chen et al., 2018; Lawrence et al., 2015) was assessed both pre and post manipulation within study 1 (with an additional timepoint of one-week post study added for study 2) in addition to post manipulation explicit food preference (Hollands & Marteau, 2016) (again, with an added one-week post study timepoint for study 2).

Both studies were pre-registered, and data is freely available (Study 1: https://osf.io/n4cb3/; Study 2: https://osf.io/4ryg7/).

2. Study 1: Inhibitory control training

We hypothesised that: i) Participants who receive a positive message related to ICT effectiveness and active ICT will show greater changes in food value (increase in healthy/decrease in unhealthy) in comparison to other training groups, ii) Participants who receive active training and a positive message related to training effectiveness will make healthier explicit choices in comparison to other training groups, iii) Participants who receive a positive message (and active training) or a positive message (and control training) will show greater changes in food value and make healthier explicit choices, compared to a group with no positive message and control training (primary hypothesis).

2.1. Method

2.1.1. Participants

One hundred and twenty-nine participants aged between 18 and 82 years (Mean age = 28.79 ± 12.86) completed the online study. The sample included 77 females (Mean age = 28.17 ± 12.63) and 52 males (Mean age = 29.71 ± 12.63) with a mean BMI of 25.02 kg/m^2 (±5.34). To be eligible for participation, participants were required to be aged over 18 and have no (self-reported) history of eating disorders. Participants were recruited through posters and online advertisements targeting the student and wider community (N = 79), or through Prolific Academic (N = 50). Individuals recruited through advertisements were entered into a prize draw (for one of two £50 Amazon vouchers), whereas Prolific Academic participants were paid £1.88 for completing the study. Participants did not differ significantly on measured demographic variables dependent on recruitment method (age and sex, see Supplementary Table 1). An a-priori power analysis indicated that 128 participants ($d = 0.30$, $\alpha = 0.05$, $1 - \beta = 0.80$) were required to identify a within*between interaction (group*time). Ethical approval for both studies was granted by the University of Liverpool Health and Life Sciences Ethics Committee (approval code: 4007).

2.1.2. Measures

2.1.2.1. Inhibitory control training task. To identify potential differences in outcomes based upon training content, participants completed a food-specific go/no-go task with either active training (100% inhibit to unhealthy food items) or control training (50% inhibit to unhealthy foods, 50% respond to unhealthy foods) contingencies. Images of 6 healthy (e.g., fruits, vegetables) and 6 unhealthy (e.g., chocolate, crisps/chips) foods were used within the trials, with images presented individually in random locations on screen. Participants were asked to withhold responses on trials where a yellow coloured border surrounded the food image (no-go trial), and provide a response (by pressing the spacebar) where no border was present (go trial). After 10 unrecorded practice trials, both active and control training tasks consisted of 200 trials (100 go, 100 no-go) with an untimed comfort break provided after 100 trials. Each image remained on screen for 1500 ms (or until a response was provided), and participants were provided with feedback after each trial ('correct' or 'incorrect' presented for 250 ms after response (or no response) provided).

2.1.2.2. Belief manipulation. To influence participant beliefs prior to participation in the ICT task, participants in the ICT message conditions were asked to read a short message describing ICT in a positive way (in terms of purpose, effectiveness and application) in relation to unhealthy food choice and preference (see supplementary materials). Prior to the current study, three potential versions of the ICT message were piloted to 41 participants (including those familiar and unfamiliar with ICT research) who were asked to rate the messages from best (i.e., accessible, believable) to worst. To ensure that cognitive demand was consistent between conditions, participants in the control message conditions were provided with a message matched for length and complexity on an unrelated topic (MMR vaccination).

Participants were asked to read the information carefully, and forewarned that they would be asked questions about the information contained within the message to ensure they fully engaged with the material presented. In all conditions, after completing ICT (or control training), participants were asked three multiple choice questions related to the information (either ICT or MMR) that they were presented with. Participants in the ICT message conditions also responded to one critical question to assess the extent to which the ICT message was believed *'How effective do you believe ICT is as an intervention'* which was scored on a visual analogue scale (VAS) from −100 (not at all) to +100 (extremely) (control message participants responded to an identical question in relation to the MMR vaccination). We assumed scores ~0 would be indicative of no strong belief in the message, which would be likely under no awareness of ICT or information regarding the effectiveness.

75% of participants correctly responded to at least two of the three questions presented ($M = 2.10 \pm 0.95$). A one-sample *t*-test was performed to assess the extent to which the ICT manipulation message was believed by participants. The results showed that the sample mean for the critical question differed significantly from 0 ($M = 17.08 \pm 38.83$), indicating that the manipulation message was effective ($t(67) = 3.63$, $p = .001$, $d = 0.44$).

2.1.2.3. Food value. Participants were presented with images of 10 healthy and 10 unhealthy food items and asked to rate the appeal of each image. For each image category, items were included from the training task (N = 6) in addition to untrained, novel stimuli (N = 4), with responses measured on a VAS ranging from −100 (not at all appealing) to +100 (extremely appealing). Task responses were used to calculate mean appeal scores for healthy and unhealthy food items.

2.1.2.4. Explicit preference. To assess explicit preference for healthy and unhealthy food items, participants completed a forced choice task, where they were presented with 8 food images (4 healthy, 4 unhealthy) and asked to select the two items that they would most like to consume given the opportunity. Food images included equal numbers of both sweet (e.g., chocolate, apples) and savoury (e.g., chips/crisps, cucumber sticks) options. A combined score was calculated based on participant selections, with unhealthy food items scored as 0, and healthy food items scored as +1 (in line with previous research (see Hollands & Marteau, 2016)). This resulted in a combined score ranging between 0 (two unhealthy options) and 2 (two healthy options).

2.1.3. Procedure

All tasks were presented online using Inquisit web 5 (Millisecond Software, SA). Participants provided informed consent, then completed basic demographic measures (age, sex, height, weight). This was followed by the food value measure (pre manipulation/task), after which participants were randomly allocated to one of four belief manipulation message and ICT task combinations (ICT message and ICT (N = 33); ICT message and control training (N = 35); control message and ICT (N = 38); control message and control training (N = 23)), where the manipulation (or control) message was presented prior to the task, with message memory assessed after the task. Participants then completed the second food value measure (post manipulation/task), followed by the explicit preference task. Participants also completed a funnelled debrief, where a task image was displayed (a healthy food item with a border surrounding it) and participants were asked to select what they would expect the correct response to be for that image (press the spacebar, do not press the spacebar, unsure).[1] Finally, participants were asked to describe what they thought the true aims of the study were (using a free text box), before being debriefed. The study took approximately 20 min to complete.

2.1.4. Statistical analysis

To analyse food value changes dependent on condition, 4 (condition: ICT message and ICT; ICT message and control training; control message and ICT; control message and control training) x 2 (time: pre manipulation, post manipulation) ANOVAs were conducted for healthy and unhealthy food value scores, with significant interactions analysed using post hoc pairwise comparisons (with a Bonferroni correction). Explicit food preference was analysed using a one way ANOVA and a post hoc

[1] Due to a data storage error, data related to the debrief portion of the study is not available.

Tukey test (with condition as the independent variable), however, we also examined these effects using Chi-square due to the nature of the data (scores between 0 and 2, see supplementary materials). Analysing the data using a 2 (message: control, ICT message) x 2 (training: control, ICT) x 2 (time: pre manipulation, post manipulation) model is also reported in supplementary materials.

2.2. Results

2.2.1. Participant demographics

Participant demographic information is presented in Supplementary Table 2.

2.2.2. Healthy food value

The healthy food value analysis revealed that there was no significant main effect of time (F (1, 125) = 3.12, p = .080, ηp^2 = 0.02), condition (F (3, 125) = 2.12, p = .103, ηp^2 = 0.05) or a time by condition interaction (F (3, 125) = 1.86, p = .139, ηp^2 = 0.04).

2.2.3. Unhealthy food value

The above analysis was repeated using unhealthy food value as the dependent variable. While there was no main effect of condition (F (3, 125) = 1.37, p = .255, ηp^2 = 0.03), there was a significant main effect of time (F (1, 125) = 26.44, p < .001, ηp^2 = 0.18), in addition to a significant time by condition interaction (F (3, 125) = 4.72, p = .004, ηp^2 = 0.10). This was due to significantly lower food value scores post manipulation (relative to pre-manipulation) in both the ICT message/ICT group (p < .001) and ICT message/control training group (p < .001). The two groups who received the control message (with either ICT or control training) did not differ significantly in terms of food value scores pre and post manipulation (p = .393 and p = .509 respectively, Fig. 1) (see Supplementary Table 3 for descriptive statistics).

2.2.4. Explicit preference

The analysis revealed a significant main effect (F (3, 125) = 4.85, p = .003, ηp^2 = 0.10), with post hoc tests revealing this was due to participants making an increased number of healthy choices in the ICT message/ICT group in comparison to the control message/ICT group (p = .007). A significant difference was also found between the ICT message/control training group and the control message/ICT group, with the ICT message/control training group making an increased number of healthy choices (p = .008). No other groups differed significantly (p > .05 in all cases, Fig. 2).

2.3. Interim summary

Providing participants with a positive manipulation message related to cue-ICT prior to training significantly reduced unhealthy food value, irrespective of the type of training provided (active or control). Interestingly, cue-ICT had no significant effect on food value where the control message was presented, which raises questions in relation to the role of participant beliefs within CBM contexts.

3. Study 2: Evaluative conditioning

While contingency awareness is more routinely assessed within evaluative conditioning studies (e.g., Kattner, 2012; Zerhouni et al., 2019), the extent to which beliefs in relation to training can influence outcome measures of food choice and preference has not yet been independently investigated. Work by Benedict et al. (2019) discovered that EC effects are vulnerable to misinformation, and providing participants with false information after an event can influence both explicit memory and attitudes. Additionally, the longevity of the effects from a single EC session is unknown in eating behaviours: work by Houben et al. (2010) demonstrated that participants consumed significantly less alcohol one week after an EC intervention, and work by Shaw et al. (2016) demonstrated that an EC training session reduced soda consumption for the week following training. Therefore, the aim of the second study was to investigate how belief manipulation and training type influenced EC training outcomes, and whether training effects were still evident one week after training. We hypothesised that: i) Participants who are provided with a positive EC message in addition to active EC training will show greater changes in food value in comparison to other training groups (primary hypothesis), ii) Participants who are provided with a positive EC message in addition to active EC training will make an increased number of healthy explicit choices in comparison to other training groups, iii) Manipulation related effects will still be evident one week after training has been completed. We also investigated potential explanatory mechanisms for manipulation effects, including belief in science, social desirability and cognitive restraint.

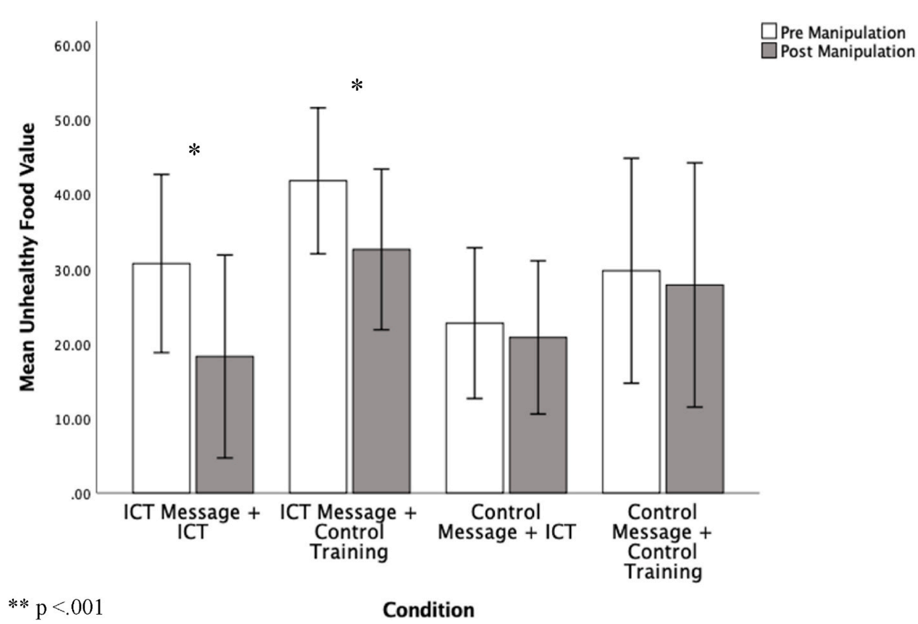

Fig. 1. A bar chart displaying mean unhealthy food value scores pre and post manipulation. Bars represent 95% CI.

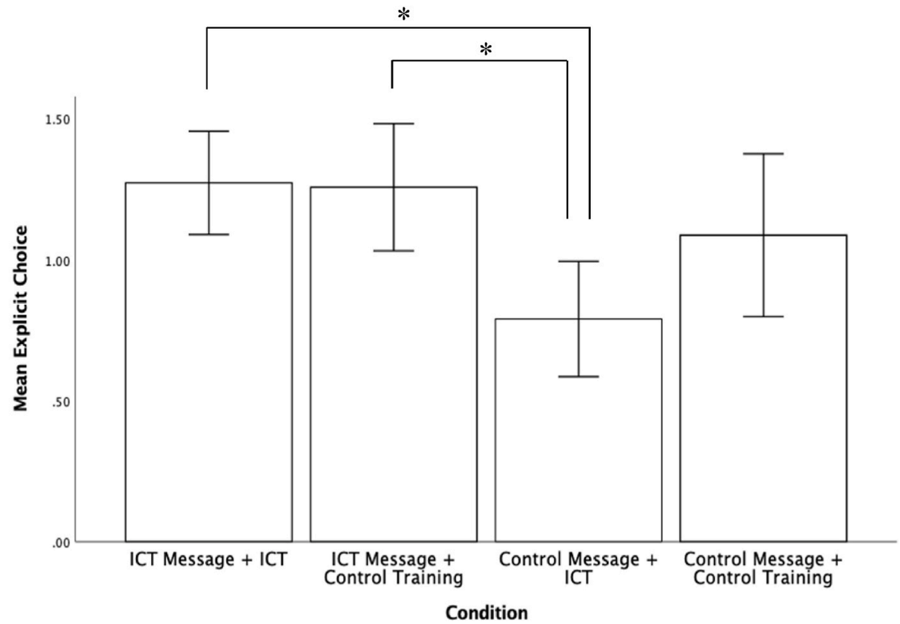

Fig. 2. A bar chart displaying mean explicit preference scores for each condition. Bars represent 95% CI.

3.1. Method

3.1.1. Participants

One hundred and thirty-nine participants fully completed part one of the study. Participants were aged between 18 and 61 years (*Mean age* = 29.01 ± 9.58), with 86 males (*Mean age* = 28.17 ± 9.56) and 53 females (*Mean age* = 30.38 ± 9.54) with a mean BMI of 24.93 (±5.39). All participants were recruited through Prolific Academic, and received £3 for completing both parts of the study (£2 for part 1, £1 for part 2). Participants were aged over 18 at the time of the study, and self-reported no history of eating disorders. An a-priori power analysis demonstrated that 128 participants ($d = 0.30$, $\alpha = 0.05$, $1 - \beta = 0.80$) were required to identify a within*between interaction (group*time), however, we recruited additional participants (~10%) to account for potential attrition between the two parts of the study.

3.1.2. Measures

Measures used within the second study were identical to those used in study one with the below exceptions.

3.1.2.1. Evaluative conditioning task. Similarly to study one, participants completed either active (100% unhealthy food and negative health outcome image pairings) or control (50% unhealthy food images paired with negative health outcome images, 50% paired with positive health outcome images) Evaluative Conditioning (EC) training. Healthy and unhealthy food images used within the task were identical to those used in the ICT task, and positive and negative health outcome images were selected based upon previously conducted pilot work (see Masterton et al., 2021). Participants were asked to respond to the location of pairs of images (food image followed by health outcome image) on the screen using the 'E' (for images presented on the left) and 'I' (for images presented on the right) keys. Participants completed 200 trials in total (100 healthy food images, 100 unhealthy food images) and were provided with an untimed comfort break after 100 trials. Each image was presented on screen for a minimum of 1000 ms, and the second image remained on screen until the participant provided a response. Feedback was provided on a trial by trial basis, with 'correct' or 'incorrect' presented on the screen for 250 ms.

3.1.2.2. Belief manipulation. In line with the ICT belief manipulation, participants in the EC message conditions were presented with a paragraph describing EC positively in relation to decreasing unhealthy food preference. The EC message was matched to the original ICT message in terms of structure and complexity, with only the critical information modified to ensure the messages were consistent across studies (see supplementary materials). The MMR based control message from study one was used for participants in the control groups, and identically to study one, participants in all groups were asked three multiple choice questions in relation to the content of the messages they had read (after completion of training). Participants in the EC message groups were also asked a critical question to identify the effectiveness of the belief manipulation '*How effective do you believe EC is as an intervention*' (control group participants completed an identical question related to the MMR vaccination).

Participant performance in relation to EC multiple choice questions was strong, with 90.70% of participants correctly responding to at least two of the three presented MCQs ($M = 2.44 \pm 0.73$). Similarly to study one, a one sample *t*-test was conducted to assess the effectiveness of the message manipulation. The results showed that the mean response for the critical question significantly differed from 0 ($M = 27.52 \pm 37.45$), again, indicating that the manipulation message was effective ($t(60) = 5.76$, $p < .001$, $d = 0.73$). There was also no significant difference in critical question response between the ICT (study 1) and EC (study 2) message ($t(127) = 1.55$, $p = .123$, $d = 0.27$), indicating strength in the belief following message manipulation did not differ significantly across studies.

3.1.2.3. Socially desirable response set five item survey (SDRS-5, Hays et al., 1989). Participants completed the SDRS-5, a five-item scale that measures social desirability by asking participants questions about their typical responses to various everyday situations. Participants were asked to respond on a scale of 1 (definitely true) to 5 (definitely false), with only extreme responses (i.e., either 1 or 5 depending on the direction of the question) contributing towards the final score. Extreme responses were scored as '1', resulting in a possible score ranging from 0 (low social desirability) to 5 (high social desirability).

3.1.2.4. Belief in science scale (BISS, Farias et al., 2013). The extent to which participants valued science as an information source was measured using three questions from the BISS (items with the highest factor loadings (Dagnall et al., 2019)). BISS responses were measured on a 6 point likert scale, ranging from 1 (strongly disagree) to 6 (strongly agree). Scores for each question were totalled to create an overall score (with higher scores indicating stronger belief in science), and internal reliability measures indicated that consistency was good between items ($\alpha = 0.81$).

3.1.2.5. Three factor eating questionnaire – Revised 18 item (TFEQ-R18, Karlsson et al., 2000). Participants completed the TFEQ-R18 to identify potential differences in eating patterns and behaviours. This questionnaire consists of 18 items which load onto three factors; cognitive restraint, uncontrolled eating and emotional eating. Participants are presented with various statements in relation to their eating behaviours and asked to indicate how much they feel that each statement applies to them (on a four-point scale). Higher scores for each factor indicate greater instances of that behaviour in relation to participants food behaviours. Internal reliability ranged between acceptable (cognitive restraint, $\alpha = 0.69$) and good (uncontrolled eating, $\alpha = 0.83$; emotional eating, $\alpha = 0.81$) for individual factors.

3.1.3. Procedure

Participants completed all tasks online using Inquisit web 6 (Millisecond Software, SA). Participants provided informed consent and completed demographic measures (including age, sex, height and weight) in addition to the TFEQ-R18. Identically to the first study, participants then completed the first food value measure (pre manipulation/task) and were allocated to one of four message and task combinations (EC message and EC training (N = 29); EC message and control training (N = 32); control message and EC training (N = 37); control training and control message (N = 41)) where the manipulation (or control) message was displayed, followed by the task, then the message memory measure. They then completed the second food value measure (post manipulation/task) before completing the explicit preference task (post manipulation/task). Participants finally completed the SDRS-5 and BISS before being thanked and informed they would be contacted in a week to complete the second part of the study.

One week later, participants were contacted to complete the follow up measures. They completed the food value measure for a third time (one week post manipulation/task) in addition to the explicit preference task (one week post manipulation/task). After this, participants completed a funnelled debrief (identically to study one), where they were asked to identify the image that would be follow a healthy food item image (either positive or negative health outcome) were it presented in the task they had completed the week before. They were also asked to describe what they believed the true aims of the study to be before receiving a debrief.

Participant attrition was higher than anticipated, with 103 participants (74%) completing both parts of the study (EC message and EC training (N = 23/79%); EC message and control training (N = 21/66%); control message and EC training (N = 29/78%); control training and control message (N = 30/73%)).

3.1.4. Statistical analysis

Identically to study one, food value changes dependent on condition were analysed using 4 (condition: EC message and EC; EC message and control training; control message and EC; control message and control training) x 2 (time: pre manipulation; post manipulation) ANOVAs for healthy and unhealthy food value scores (with significant interactions analysed using post hoc pairwise comparisons with a Bonferroni correction), and explicit preference scores were analysed using a one way ANOVA (with a post-hoc Tukey test and exploratory Chi-square). Due to the additional time-point within this study, 4 (condition: EC message and EC; EC message and control training; control message and EC; control message and control training) x 3 (time: pre manipulation; post manipulation; one week post manipulation) ANOVAs were performed for healthy and unhealthy food value scores, in addition to a 4 (condition: EC message and EC; EC message and control training; control message and EC; control message and control training) x 2 (time: post manipulation, one week post manipulation) ANOVA for explicit food preference. Analyses were run separately for follow-ups, to ensure any attrition did not reduce the power of post-manipulation analysis). Exploratory analyses were also conducted related to belief in science, social desirability and cognitive restraint (see supplementary materials). Analysing the data using a 2 (message: control, EC message) x 2 (training: control, EC) x 2 (time: pre manipulation, post manipulation) model is also reported in supplementary materials.

3.2. Results

3.2.1. Participant demographics

Participant demographic information is presented in Supplementary Table 5.

3.2.2. Healthy food value

The analysis revealed that while there was a significant main effect of time (F (1, 135) = 34.21, $p < .001$, $\eta p^2 = 0.20$) (with higher healthy food value scores post manipulation ($M = 37.47$, $SD = 29.53$ compared to $M = 30.41$, $SD = 29.59$)), there was no significant main effect of condition (F (3, 135) = 0.08, p = .969, $\eta p^2 = 0.002$) and no time by condition interaction (F (3, 135) = 0.33, p = .807, $\eta p^2 = 0.01$).

3.2.3. Unhealthy food value

The analysis was repeated with unhealthy food value scores as the dependent variable. While no main effect of condition was found (F (3, 135) = 0.05, p = .985, $\eta p^2 = 0.001$), there was a significant main effect of time (F (1,135) = 21.96, $p < .001$, $\eta p^2 = 0.14$) in addition to a significant condition by time interaction (F (3,135) = 6.52, $p < .001$, $\eta p^2 = 0.13$). Subsequent analyses revealed that this was the result of significantly lower scores for unhealthy food value post manipulation for the EC message and EC training group ($p < .001$). No other significant differences were found ($p > .05$ in all cases, Fig. 3).

3.2.4. Explicit preference

The explicit preference analysis revealed that there was no significant main effect of condition (F (3,135) = 0.63, p = .596, $\eta p^2 = 0.01$).

3.2.5. Healthy food value (follow up)

To investigate the duration of potential training related effects, the above analyses were repeated with the inclusion of an additional time point (one week post training). The analysis revealed that while there was a significant main effect of time for healthy food value scores (F (2, 198) = 10.07, $p < .001$, $\eta p^2 = 0.10$), there was no significant main effect of condition (F (3, 99) = 0.03, p = .992, $\eta p^2 = 0.001$) and no time by condition interaction (F (6, 198) = 0.49, p = .816, $\eta p^2 = 0.02$).

3.2.6. Unhealthy food value (follow up)

When the analysis was repeated using unhealthy food value scores as the dependent variable, while there was no main effect of condition (F (3, 99) = 0.03, p = .994, $\eta p^2 = 0.001$), there was a significant main effect of time (F (2, 198) = 10.54, $p < .001$, $\eta p^2 = 0.10$) and a significant condition by time interaction (F (6, 198) = 3.52, p = .002, $\eta p^2 = 0.10$). The interaction was due to significantly lower unhealthy food value scores for the EC message and EC training group both immediately post manipulation ($p < .001$) and one-week post manipulation ($p < .001$) in comparison to baseline. There was also a significant difference within the EC message and control training group, with participants scoring lower for unhealthy food value one week post intervention compared to pre manipulation (p = .036). No other significant differences were found ($p > .05$ in all cases, Fig. 4) (see Supplementary Table 7 for descriptive

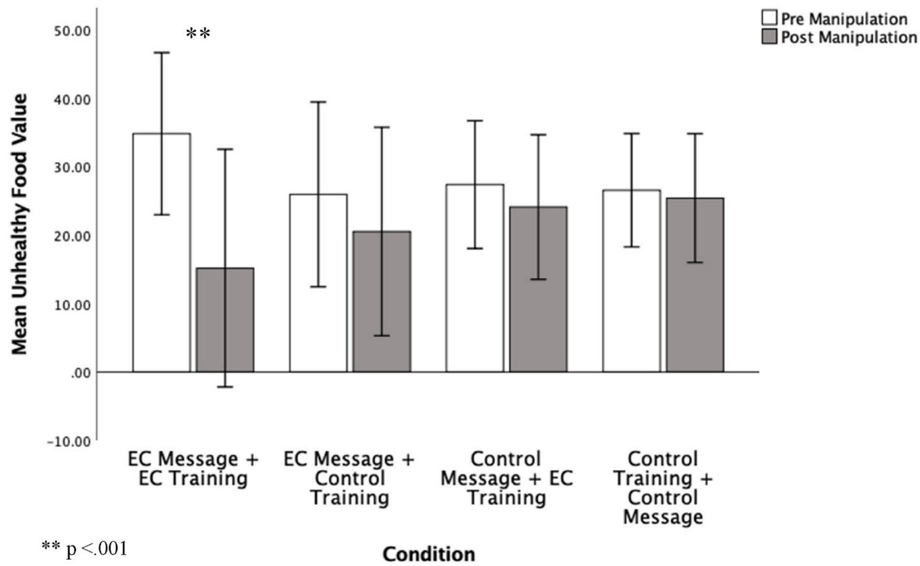

Fig. 3. A bar chart displaying mean unhealthy food value scores pre and post manipulation. Bars represent 95% CI.

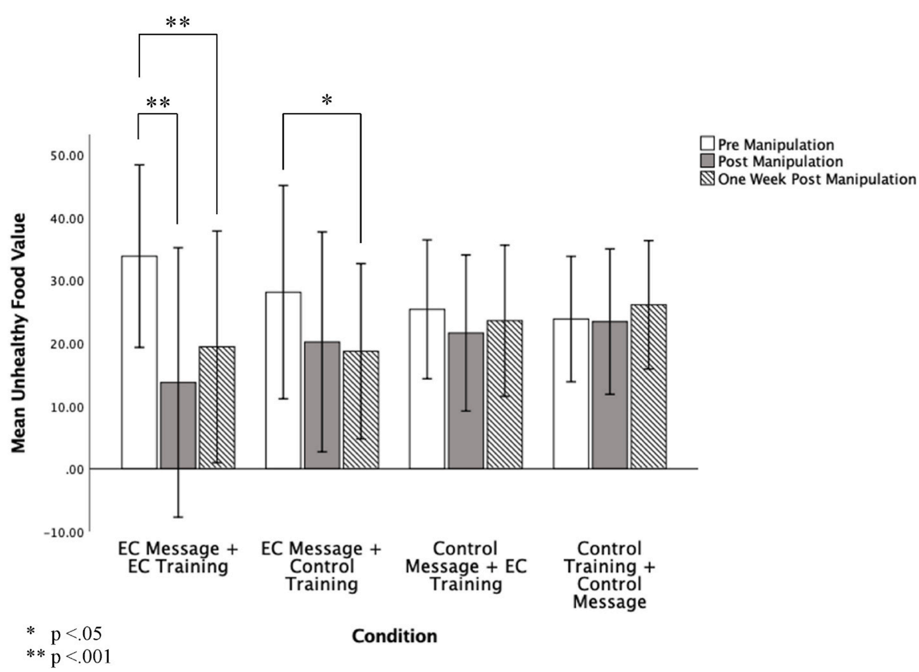

Fig. 4. A bar chart displaying mean unhealthy food value scores pre, post and one week post manipulation. Bars represent 95% CI.

statistics).

3.2.7. *Explicit preference (follow up)*

The explicit preference analysis was also repeated with the additional one-week post manipulation timepoint, and while there was a significant main effect of time (F (1, 99) = 7.86, p = .006, $\eta p^2 = 0.07$), there was no main effect of condition (F (3, 99) = 0.29, p = .831, $\eta p^2 = 0.01$) and no significant time by condition interaction (F (3, 99) = 1.18, p = .320, $\eta p^2 = 0.04$).

3.2.8. *Supplementary analyses*

To investigate potential mechanisms for manipulation effects, we conducted exploratory analyses, repeating the main analyses, and including belief in science, social desirability and cognitive restraint as covariates. Inclusion of these variables did not meaningfully influence the results (see supplementary materials).

4. Discussion

The aim of the current research was to investigate the impact of manipulating beliefs related to training effectiveness across two CBM paradigms (Inhibitory Control Training and Evaluative Conditioning). In study 1, the analyses revealed that while message and training manipulations had no influence on healthy food value, unhealthy food value only decreased when a positive ICT message was presented to participants, irrespective of training content (active or control). There was also evidence to suggest that participants who received positive ICT messages (paired with either active or control training) made an increased number of healthier explicit choices than participants in the control message and active training group. In study 2, manipulations had no influence on healthy food value, however, participants who received a positive EC message and active EC training had lower unhealthy food value ratings both immediately post manipulation and one week post manipulation. Although participants presented with a positive EC message and control training showed no significant decreases in unhealthy food value immediately post training, there was a significant decrease in unhealthy food value one week post manipulation. Similarly to study 1, control message manipulations (irrespective of training content) resulted in no significant changes to unhealthy food value across all three time points.

It was hypothesised that participants who received a positive training message and active training (either ICT or EC) would show greater changes in food value in comparison to other training groups. In both studies, while the manipulations did not have any significant impact on healthy food value, participants who experienced the training message and active training manipulations had significant decreases in unhealthy food value both post manipulation (study 1 and 2) and one week post manipulation (study 2). The difference between healthy vs unhealthy food value may be partially explained by the framing of our message, as participants were informed ICT and EC directly influenced *unhealthy* food behaviours ('… *this type of training reduces how pleasurable you find unhealthy foods and improves your ability to resist eating unhealthily*'), but made no mention of healthy food behaviour.

Previous work investigating CBM feasibility discovered that positive manipulation messages increased participant expectations for training (Rabipour & Davidson, 2015), and work by Kattner (2012) discovered that asking participants to memorise training image pairings increased training effectiveness. As the positive message promoted the potential benefits of CBM (in relation to reductions in unhealthy food consumption), it may be that this increased expectations in relation to training efficacy while also highlighting responses and pairings utilised within training tasks, resulting in significant decreases to unhealthy food value within these groups.

Notably, across both studies, control message participants displayed no changes to unhealthy food value, irrespective of training content (active or control). This may suggest that CBM as an isolated intervention is not robust enough to elicit changes to explicit measures of unhealthy food value and preference, with the observed effects here appearing to be at least partially dependent on the presentation of the manipulation message, irrespective of the actual training content itself. While previous research has suggested that CBM can positively influence food choice and value ((e.g., Chen et al., 2018; Hollands et al., 2011; Oomen et al., 2018), in the current study, there was only limited evidence to suggest that the CBM training independently influenced unhealthy food value and choice, supporting the findings of previous work that did not find evidence to support the use of CBM training within food contexts (e.g., Becker et al., 2015; Carbine et al., 2021; Masterton et al., 2021). The inconsistent outcomes reported throughout the literature in relation to training effectiveness could indicate that factors external to training (and not consistently measured (such as beliefs or expectations in relation to training impact)) may play an important role in successful intervention outcomes.

Where it has been measured, most studies identify at least *some* participants who can correctly guess the aim of the training provided despite this not being addressed by the researchers (e.g., Di Lemma & Field, 2017; Lawrence et al., 2015), which could suggest that individual-level variations between participants (e.g., beliefs in relation to CBM or the expectation that training will have a positive impact on behaviour) may have a substantial influence on both training engagement and outcomes (Beard et al., 2012; Boot et al., 2013). This is an important consideration for future studies, and researchers should further investigate individual variations within CBM contexts to fully identify the impact of CBM training as standalone paradigms.

While the content of training did not appear to influence ICT positive message outcomes, for EC, the interaction between manipulation message and training type appears to be more complex. Although a positive EC message and active EC led to reductions in unhealthy food value both immediately and one week post manipulation, a positive EC message and control training only led to a significant reduction in unhealthy food value when comparing pre manipulation and one week post manipulation. In comparison to ICT, EC is arguably a simpler (and more predictable) task, with participants required to respond to the location of each stimuli pair after both images are displayed (rather than withholding/rapidly providing responses to a single stimuli item), potentially resulting in decreased task demand (Wessel, 2018) and increased trial duration, which may have implications for participant awareness and training effectiveness. Work by Benedict et al. (2019) highlighted that EC effects are highly vulnerable to misinformation, which can influence both explicit memory and attitudes towards training stimuli. The presentation of inconsistent information (through positively describing active training and providing control training) may have increased uncertainty in relation to training purpose within this group, which could have reduced the immediate impact of the manipulation message. While this explains the lack of significant results immediately post training for EC, this does not explain why the decrease in unhealthy food value was significant one week post training. Interestingly, in the follow up contingency awareness assessment, 67% of participants who received the control training and positive message manipulation identified that a healthy food image would be followed by a positive health outcome, despite this not always being the case for the training they completed. This may indicate that the content contained within the positive message (i.e., informing participants of active training pairings) may have had a greater influence on food value in the week following the intervention (despite active training not being provided), however, future research would need to investigate factors such as message memory to further isolate these effects.

Although it was hypothesised that both ICT and EC manipulations would result in healthier explicit choices, results varied across studies. While there was some evidence within study 1 to suggest participants in the positive message groups (both active and control) made healthier explicit choices than those in the control message and active ICT group, it is not clear why the true control group (control message and control training) did not significantly differ from the positive message groups, or why there was no significant effect of manipulation on explicit preference in study 2. While previous work investigating CBM has utilised online forced choice measures of preference (e.g., Hollands et al., 2011; Veling et al., 2013), as choices have no real-world consequences for participants, there are concerns in relation to the validity of the measure (Hollands & Marteau, 2016). It is also possible that the manipulation message (combined with the short nature of the explicit preference task) led to increased bias within this measure, with participants deliberately controlling their responses (i.e., specifically selecting healthy or unhealthy items) to support or refute the message received during the manipulation (although we found no evidence to support social desirability mechanisms within study 2). Notably, the follow-up analysis of this study was slightly underpowered due to attrition. Future work should attempt to systematically explore potential bias within forced choice tasks to investigate their validity in relation to real world food choice contexts (Klein et al., 2012).

While the manipulation messages did significantly influence unhealthy food training outcomes, the extent to which participants were motivated to change their behaviour was unclear. The message manipulations did appear to be effective overall, however not all individuals within the study necessarily believed the message presented (some participants scored <0 on the manipulation check). Additionally, we did not measure belief in CBM training in participants who did not receive the manipulation message, therefore we were unable to compare belief in training between manipulation and control message groups. It is also worth noting that the manipulation check is limited given we did not measure pre-message beliefs, and therefore could not infer a *change* in beliefs as a result of exposure to the manipulation message (but measuring beliefs prior to the message may have increased demand characteristics). Previous work has highlighted that participants can question the credibility of CBM approaches (Beard et al., 2012), and it may be that individual level variations in training belief (in addition to motivation to change (Field et al., 2020)) could also influence engagement with training and training outcomes. Additionally, while proxy measures of food intake (such as value and choice) are used throughout the literature (e.g., Chen et al., 2018; Hollands & Marteau, 2016; Lawrence et al., 2015), the extent to which these measures are related to real world consumption behaviours is relatively understudied. Work by Wang et al. (2017) discovered that while participants evaluated chocolate more negatively after training, there were no significant differences in relation to actual chocolate consumption, and work by Kakoschke et al. (2017) found that although combined CBM training resulted in reduced unhealthy snack food choice, there was no significant influence on food intake. Future research should investigate the impact of belief manipulations on more objective measures of consumption (such as bogus taste tests (Robinson et al., 2017)) within participants motivated to change their behaviour (i.e., individuals wishing to reduce unhealthy food consumption). This would help to identify the true potential of belief manipulations (in CBM contexts) within populations most likely to benefit from intervention participation.

While we focused on explicit measures of preference (i.e., value and choice) within the current study, it would be interesting to examine the influence of message manipulations on implicit measures of preference (given the associations between implicit food preference and long-term weight gain (Nederkoorn et al., 2010)). Similarly to explicit preferences, the influence of CBM on implicit preferences for unhealthy foods is unclear: While Lebens et al. (2011) found that post-training, participants had more negative associations with unhealthy foods (compared to control group participants), meta-analytic work by Jones et al. (2016) revealed that the influence of ICT on implicit preferences was not robust across various appetitive stimuli. Previous work has discovered that implicit preferences can be influenced by propositional knowledge (De Houwer, 2006), therefore it is likely that these preferences are also susceptible to the influences of experimental belief manipulations, which could be an interesting avenue for future research.

In conclusion, the aim of the current research was to investigate the influence of directly manipulating beliefs in relation to CBM effectiveness (cue-ICT and EC) on training outcomes. The results indicated that unhealthy food value and choice were only reduced where a positive manipulation message was presented to participants, and that there was no significant change to unhealthy food value where no positive message was presented beforehand (irrespective of training content). These findings raise questions in relation to the role of awareness and expectancies within cognitive training tasks: future research should further explore these variables within CBM contexts to improve behavioural and intervention outcomes.

Statement of contribution

SM, AJ and CAH designed the study. SM and AJ wrote the preregistration. SM collected the data. SM drafted the manuscript. All authors provided comments and approved the final manuscript.

Ethical statement

Both studies conducted as part of this manuscript were approved by the University of Liverpool Health and Life Sciences Research Ethics Committee prior to research commencement (reference number 4007). All participants provided consent prior to study participation, and were fully debriefed (and provided with appropriate support information/ researcher contact details) at the end of the study.

Declaration of competing interest

CAH has received funding from the American Beverage Association and speaker fees from the International Sweeteners Association for unrelated research. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.106041.

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