Testing The Effectiveness Of A Gamified Emotional Cognitive Bias Modification Task As An Intervention For Low Mood: Randomised Controlled Trial

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Abstract

Background: Emotion recognition bias in depression is well documented and is proposed to play a causal role in depression. A Cognitive Bias Modification (CBM) intervention targeting the bias in emotional expression perception was developed, but despite robust training effects on emotion perception, the effect on mood was unreliable and weak. We propose a new gamified version of CBM (GCBM) to address potential limitations that may attenuate therapeutic effects.

Objective: This study aims to test the effectiveness of GCBM in altering the perception of emotional facial expressions and improving the immediate mood of healthy participants.
Study 1 aimed to investigate the effectiveness of a single session of GCBM on emotion perception and to assess whether the gamified version of the task would produce the same robust training effects on the interpretation of emotional expressions as the original CBM.
Study 2 aimed to compare the effectiveness of a single session of CBM training, CBM (no training) control, and GCBM training on immediate mood.

Methods: We reported two between-subjects online experimental studies that recruited participants from the general population. Study 1 (N = 58) tested the effectiveness of GCBM in changing participants' responses to ambiguous facial expressions. The primary outcome was emotion recognition bias, measured by increased identification of happy faces. Study 2 (N = 916) compared the effects of a single session of GCBM training, CBM training and CBM control conditions on immediate mood. The primary outcome was immediate mood after the training, measured by the Immediate Mood Scaler (IMS).

Results: Study 1 showed that participants in the intervention condition classified more ambiguous faces as 'happy' after the training compared to controls, indicating an increased perception of happiness in ambiguous faces. (B = 1.73, P < .001). Study 2 provided evidence that GCBM training produced more positive changes in immediate mood compared to the CBM control condition (B = -3.64, P = .003) and compared to the CBM training condition (B = 1.73, P = .044).

Conclusions: These studies showed that GCBM may change participants' emotion recognition bias to ambiguous facial expressions and enhance mood compared to both CBM and control conditions. These results suggest that GCBM might be an effective intervention for addressing mood-related cognitive biases. Further exploration of GCBM's long-term effects on mood and its clinical application is needed.

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Emotion recognition bias in depression is well documented [1] and is proposed to play a causal role in depression [2]. A Cognitive Bias Modification (CBM) intervention targeting the bias in emotional expression perception was developed, but despite robust training effects on emotion perception, the effect on mood was unreliable and weak [3]. We propose a new gamified version of CBM (GCBM) to address potential limitations that may attenuate therapeutic effects.

Objective

This study aims to test the effectiveness of GCBM in altering the perception of emotional facial expressions and improving the immediate mood of healthy participants.

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We reported two between-subjects online experimental studies that recruited participants from the general population. Study 1 (N = 58) tested the effectiveness of GCBM in changing participants' responses to ambiguous facial expressions. The primary outcome was emotion recognition bias, measured by increased identification of happy faces. Study 2 (N = 916) compared the effects of a single session of GCBM training, CBM training and CBM control conditions on immediate mood. The primary outcome was immediate mood after the training, measured by the Immediate Mood Scaler (IMS).

Results

Study 1 showed that participants in the intervention condition classified more ambiguous faces as 'happy' after the training compared to controls, indicating an increased perception of happiness in ambiguous faces. (B = 1.73, *P* < .001). Study 2 provided evidence that GCBM training produced more positive changes in immediate mood compared to the CBM control condition (B = -3.64, *P* = .003) and compared to the CBM training condition (B = 1.73, *P* = .044).

Conclusions

These studies showed that GCBM may change participants' emotion recognition bias to ambiguous facial expressions and enhance mood compared to both CBM and control conditions. These results suggest that GCBM might be an effective intervention for addressing mood-related cognitive biases. Further exploration of GCBM's long-term effects on mood and its clinical application is needed.

Keywords: low mood, cognitive bias modification, gamification, emotion recognition bias, emotional facial expressions

Introduction

Depression is associated with a negative bias in the interpretation of facial emotional expressions[1,3]. This negative bias has been proposed to play an important role in the onset and maintenance of depression, as successful pharmacological interventions have been found to be associated with the reduction of negative biases [2,4]. It was previously thought that treating depression would lead to improvements in emotion recognition bias. However, there is evidence suggesting that mood improvement comes after changes in emotion recognition biases[2]. This finding implies that altering negative biases might be an effective way to improve the mood of individuals with depression [2]. Consequently, Cognitive Bias Modification (CBM) interventions that target this negative bias may reduce depressive symptoms [3].

A CBM intervention was developed to aim at changing negative biases in the perception of emotional facial expressions. [3]. This CBM technique shifts participants' responses towards more positive interpretations of ambiguous facial expressions [3]. However, the improvements in mood that are predicted to follow a reduction in negative bias by the neurocognitive models of depression have been weak and unreliable [5–8]. We conducted a meta-analysis of six CBM training studies using the same intervention to assess the overall effectiveness of this CBM technique on mood outcomes [9]. The meta-analytic results showed that the effectiveness of the CBM on mood (i.e. reducing overall depressive symptoms) was consistent with neurocognitive models of depression: indirect effects of training on improved mood were mediated by decreased negative emotional bias. However, the direct effects of training in the mediation model were in the opposite direction, with allocation to the active training condition leading to lower mood in comparison to the control condition. This was contrary to our predictions and indicated that some aspects of the active training condition were having a negative effect on mood. Overall, the indirect effects (in the therapeutic direction) and direct effects (in the non-therapeutic direction) largely cancelled each other; resulting in a weak overall effect of CBM training on mood [9].

In the CBM studies reviewed in our meta-analysis, participants were given negative (i.e., “Incorrect”) and positive (i.e., “Correct”) text-based feedback to shift the perception of ambiguous faces from sad to happy (i.e. reduce a negative cognitive bias [10]. In the CBM participants in the training condition receive more negative feedback (i.e. are told that they are incorrect) as the mechanism to change their perception of facial emotion from negative (sad) to positive (happy) judgements. Participants in the control conditions receive less negative feedback than those in the active training condition, as the CBM technique does not aim to change their responses from baseline. Based on the meta-analysis results, we speculated that the relatively frequent negative (i.e., “incorrect”) feedback in the task might elicit the negative effect of mood associated with the training condition revealed in the meta-analysis. Research suggests that continuous negative feedback decreases positive emotional experiences[11], and can trigger self-esteem problems and induce negative emotions [12]. Moreover, receiving negative feedback elicits negative emotions, which can reduce the acceptance and use of future feedback [13]. Contrary, positive feedback reduces social anxiety [14] and prevents/ attenuates depression [15].

These reported effects of negative feedback suggest that removing or changing the delivery of negative feedback may improve the effectiveness of this CBM technique on mood-related outcomes. However, in order to change emotion recognition bias, some form of feedback is necessary to drive the modification as this “corrects” the response in the intended direction. However, such feedback should be delivered in a constructive way. The education literature points to the importance of constructive feedback to increase the effectiveness of the feedback and positive emotional experience [16]. Given this information, the impact of negative feedback on cognitive interventions should be investigated in order to improve the emotional experience, and subsequent mood outcomes, of CBM.

There are different ways to give feedback to participants in cognitive tasks. We propose a new version of our previous CBM task, in which negative feedback is replaced by positive reinforcement of the desired response via gamification techniques that adapt game-like features to non-game tasks [17]. Gamification methods have been used in long and repetitive cognitive tasks to improve the engagement of participants[18,19]. The gamified version of CBM (GCBM) uses a scoring system, instead of the “correct/incorrect” feedback, to change participant’s judgments of emotional faces, and potentially improve mood outcomes after the CBM training. The participants earn points for each correct answer but do not earn any points for the incorrect answers. They earn more points for ‘correct’ answers to more ambiguous images that are harder to judge (i.e., more ambiguous faces that are more difficult to judge).

In study 1, we investigated whether replacing negative feedback with a gamified points feature delivers similar training effects to those seen in our previous studies [5–8] The hypothesis is that a single session of GCBM would result in a positive change in the recognition of emotional facial expressions, similar to CBM training. Study 2 compared the effectiveness of a single session of GCBM training, CBM training and CBM control conditions on immediate mood. Previous studies suggested that younger people benefited more from CBM training in terms of mood improvement [8] therefore, we recruited young adults between the ages of 18 and 30. We hypothesised that participants in the GCBM condition would have significantly higher mood scores after training compared to the CBM group.

Study 1

Preregistration information for this study is available on the Open Science Framework, where the experimental data can also be accessed [20].

Study 1 aimed to investigate the effectiveness of a single session of GCBM on emotion perception and to assess whether the gamified version of the task would produce the same robust training effects on the interpretation of emotional expressions as the original CBM [3]. We hypothesised that there would be a positive change in the training group`s post-training balance point (BP, the measure of bias) compared to the control group.

Method

Participants

Previous studies [5,8] demonstrated a large (*Cohen's d* = 1) change in balance point (i.e. a shift toward perception of happiness in ambiguous faces) in the intervention group compared to the control group. An a priori power analysis was conducted using G*Power [21] We calculated a sample size of a total of 54 (27 for each condition) to detect the *d* = 1 with 95% power.

We recruited 60 participants to allow for participants failing attention checks or not completing the study. We recruited participants through Prolific Academic and delivered the training using Gorilla, a platform for creating online experimental tasks [22]. Participants were reimbursed £3.75 for their time (median time is 10.19 minutes). Eligible participants were aged 18 years and over, fluent in English and had normal or corrected-to-normal vision. Participants were ineligible if they had consumed alcohol within the last 12 hours (self-report).

Ethics approval was obtained from the School of Psychological Science Research Ethics Committee at the University of Bristol (Approval Code: 14244). The study was conducted in accordance with the revised Declaration of Helsinki (2013) and the 1996 ICH Guidelines for Good Clinical Practice E6(R1).

Study Design

A between-subjects design with one factor (GCBM, no-training control) was used for this study. We tested the effectiveness of GCBM to train the positive bias in the emotion perception of participants (i.e. increasing 'happy' responses to ambiguous faces). Participants were randomised to control and training conditions with a 1:1 ratio. The balance point for emotion perception was measured before (baseline) and after training. The primary outcome was the emotion recognition bias, as assessed by the balance point (see below).

Procedure

At the beginning of the experiment, participants were presented with an information sheet and asked to complete an online consent form confirming eligibility against the criteria listed above. If participants confirmed eligibility and consent, they started the experiment by answering demographic questions. Next, the GCBM training was presented with participants being fully randomised to either the intervention or control group. After training, participants completed the Immediate Mood Scaler (IMS). Next, they filled out the feedback text box and attention check text box. Finally, they were debriefed and reimbursed via their Prolific account. The experiment took approximately 15 minutes.

Materials

Gamified Cognitive Bias Modification (GCBM)

The gamified CBM training used in this study was adapted from the CBM intervention used in our earlier work. The original CBM intervention involved repeated trials where the participant was briefly shown an image of a morphed emotional face and asked to decide whether the displayed face was happy or sad (See Figure 1 for example faces). These facial images (15 in total) were morphed between happy and sad emotions, taken from a continuum ranging from an unambiguously happy emotional face to an unambiguously sad emotional face, with ambiguous images towards the centre of the continuum (Figure 1: Example of morphed happy and sad faces). Hence, each individual stimulus differed in the proportion of each emotion presented.

The primary outcome was a "balance point", which indicated the image at which a participant was equally likely to categorize the face as happy or sad. Feedback was tailored to each participant, based on their balance point in the baseline block. For participants receiving active training, feedback aimed to shift participants' responses to categorise two more faces as 'happy'. In the control condition, feedback was given in line with their baseline balance point, meaning no change in their responses was expected. The balance point was calculated as the number of ‘happy’ responses divided by the total number of trials in the baseline/test block, and this number was then multiplied by the number of stimuli [3].

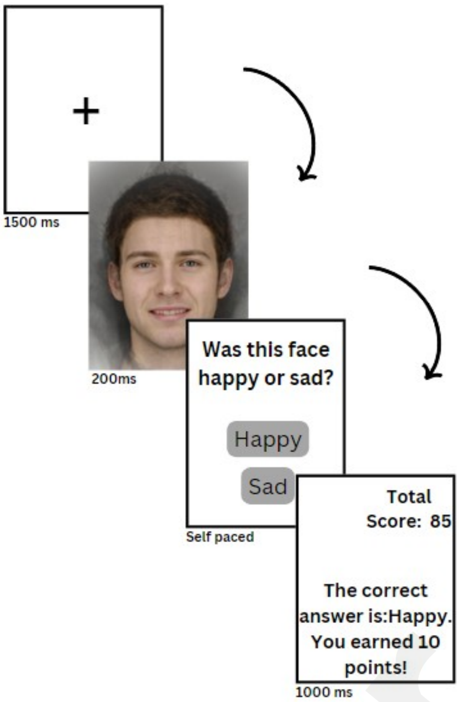
There were four blocks: baseline, two training blocks, and test. The baseline and test blocks determined the participant’s pre-training and post-training balance points. In a typical trial, a fixation cross was displayed for 600 ms, followed by a facial stimulus for 200 ms. The baseline and test blocks consisted of 45 trials; the 15 facial stimuli were each presented 3 times in random order. All participants started with a baseline block to calculate their balance points. After that they continued to do the 2 training blocks, there were 31 trials, in which images 1-2 (unambiguously happy) and 14-15 (unambiguously sad) were presented once, images 3-5 and 11-13 were presented twice, and images 6-10 were presented three times. In the training blocks, they received feedback based on their baseline balance point and the group they were in (training-control). After the training blocks, there was a test block in which the post-training balance point was calculated. The experiment took roughly 10 minutes to complete.

The new GCBM intervention included the features mentioned above, but the method of feedback to participants was changed. In the CBM training participants received positive or negative feedback as text (e.g., “Correct! That face was happy” or “Incorrect! That face was Sad”). However, in the GCBM participants earned points as a reward for correct answers but received no points for incorrect answers (Figure 2). In GCBM, more points were scored for correct answers closer to their baseline balance point so participants received a higher reward for correctly responding to more ambiguous expressions as faces closer to the balance point were more emotionally ambiguous (see supplementary materials S1 for scoring system details). Participants were able to see their total scores on the right upper corner of the screen throughout both training blocks. In the control condition, points were awarded based on a participant’s baseline balance point without any modification (i.e. participants were rewarded for responding in the same way as they responded in the baseline block), and therefore no change in their balance point was expected.

Figure 1:

Examples of morphed faces, showing unambiguously sad and happy images at the endpoints, and more ambiguous images in the centre.

Figure 2:
Example training block of Gamified Cognitive Bias Training



Immediate Mood Scale (IMS)

After the GCBM training, participants completed the Immediate Mood Scale (IMS) [23]. IMS is a self-report questionnaire that measures well-being. It consists of 22 questions and responses are made on a 5-point scale.

Demographic questions

Participants were asked about their ethnicity, gender and age.

Attention check

The participants were asked to type “seven” into a text box if they were still paying attention to the task after the IMS questionnaire.

Statistical Analysis

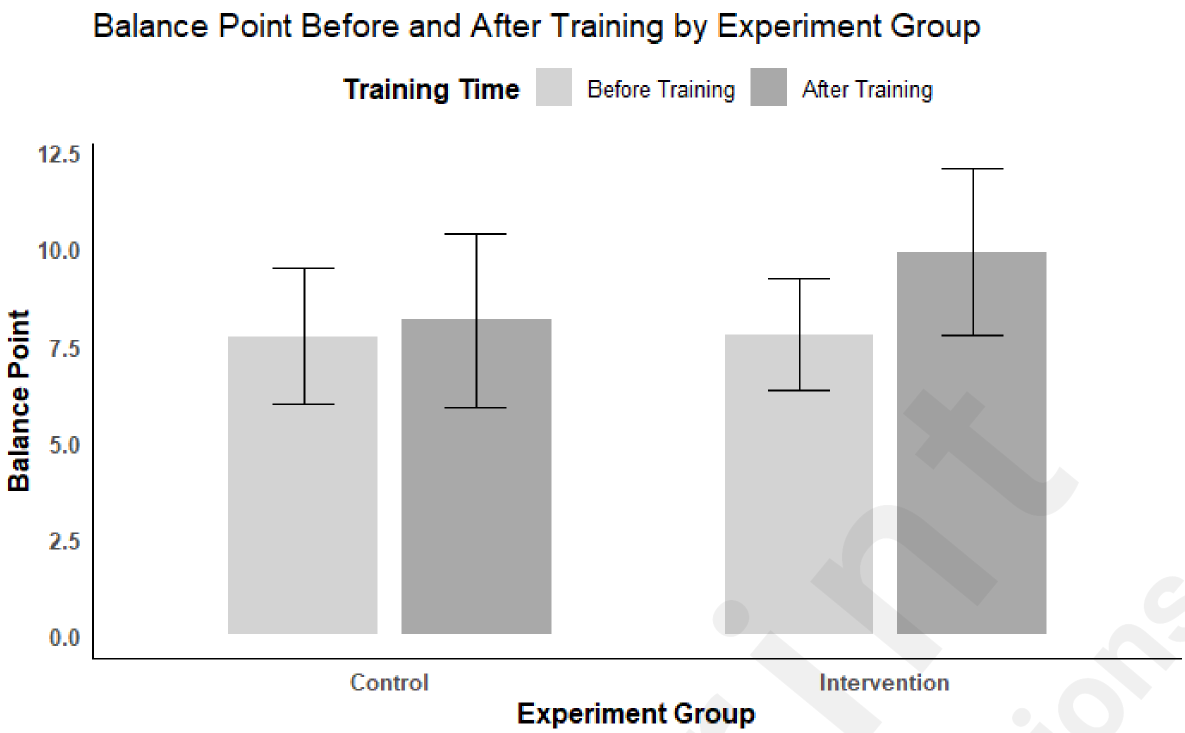
We conducted the statistical analyses using IBM SPSS Statistics for Windows, Version 28.0. We used box plots to identify and remove outliers (i.e., data points that fell 1.5 times above or below the interquartile range). There were no outliers to remove. Data were assessed for normality using skewness and kurtosis statistics and were found to meet the assumptions of normality.

We ran a linear regression analysis to compare the post-training balance points of the control and intervention groups. We adjusted for baseline balance point, age and gender, and reported adjusted and unadjusted models. The exploratory analysis investigated whether the intervention group had higher mood (IMS) scores after training compared to controls, again using regression with adjustment for baseline mood, age and gender.

Results

We collected data from 60 participants. Two participants were not eligible (consumed alcohol within 12 hours). Of the remaining 58 participants, 62.1% were women (32 women, 22 men, 4 did not state their gender). In the control condition, 58.6% were women and in the intervention condition, 65.5% were women. The mean age was 42.59 (SD = 13.38). 77.6% of the participants were White, 8.6% were Black/African/Caribbean, 6.9% were Mixed/Multiple Ethnic Groups, 3.4% were Asian, and 3.4% chose ‘other’ as an option. Figure 3 shows the average balance points for the control and intervention groups before and after the GCBM training.

Figure 3:
Graph for balance points of control and intervention groups in pre and post-training. Participants changed their responses in the intervention arm, but in the control condition responses remained the same. Higher balance points indicate participants categorised more faces as happy which suggests less negative bias when interpreting ambiguous emotional facial expressions. Error bars show SD.



The regression analysis results indicated that GCBM training led to positive changes in the balance point of participants (B = 1.77, 95% CI [0.61, 2.93], *P* = .004). This finding was robust to adjustment for baseline balance point, gender and age (see supplementary materials Table T1). This suggests that participants in the intervention condition were more likely to classify ambiguous faces as 'happy' compared to controls after the training. On average, participants in the intervention condition showed an increase of 1.77 points in their balance point.

Exploratory analysis

We did not power this study based on the mood outcome, but we conducted exploratory analyses to examine the effect of group assignment (intervention vs. control) on mood outcomes. Results showed that group assignment did not predict significant differences in post-training mood scores (B = 1.40, 95% CI [-10.73, 13.52], *P* = .82).

Study 2

Study 2 compared the effectiveness of a single session of CBM training, CBM (no training) control, and GCBM training on immediate mood. We hypothesised that participants in the GCBM condition would have significantly higher mood scores after training compared to the CBM and control CBM groups. Preregistration information for this study is available on the Open Science Framework, where the experimental data can also be accessed [24]. For Study 2, there were deviations from the protocol as the CBM control condition was added post hoc. These deviations are explained in the supplementary materials, but for clarity, we have presented the study as though all conditions were run concurrently (see Supplementary Materials S2).

Participants

The meta-analysis of CBM studies revealed an indirect effect size of g = 0.23 for the effect of training on mood outcomes [9]. An a priori power analysis was conducted using G*Power [21]. We calculated a sample size of a total of 788 (394 in GCBM and 394 CBM training conditions) would allow us to detect d = 0.2 with 80% power. A further 120 participants were recruited for the control condition (see Supplementary Materials S3 for this sample size determination).

In total, we recruited 927 participants to allow for participants failing attention checks or not completing the study through Prolific Academic. Participants were reimbursed £2.25 via Prolific for their time (median completion time was 11 minutes).

To be eligible for this study, participants had to be aged between 18 years and 30 years, fluent in English and have normal or corrected-to-normal vision. Participants were ineligible if they had consumed alcohol within the last 12 hours (self-report).

Ethics approval was obtained from the School of Psychological Science Research Ethics Committee at the University of Bristol (Approval Code: 15735). The study was conducted according to the revised Declaration of Helsinki (2013) and the 1996 ICH Guidelines for Good Clinical Practice E6 (R1).

Study Design

This experimental study used a between-subjects design with one factor of intervention (CBM control, CBM training, GCBM training) with immediate mood as the outcome. Participants were randomised to CBM and GCBM conditions with a 1:1 ratio. Participants were allocated to the control condition in a second phase of testing (see protocol deviations in supplementary materials). Mood was assessed using the IMS before and after training. The primary outcome is the difference in IMS scores between the CBM and GCBM groups.

Procedure

At the beginning of the experiment, participants were presented with an information sheet and asked to complete an online consent form in which they confirmed eligibility against the criteria listed above. If participants confirmed eligibility and consent, they started the experiment by answering demographic questions. Next, they filled out IMS questionnaire for mood measurement. Next, the training was presented (either CBM control, CBM training or GCBM training per the randomisation). After the training, they completed the IMS questionnaire again and were presented with the feedback text box and attention check text box. Finally, they were provided with the debrief and researcher information, and reimbursed via their Prolific account.

Materials

In this experiment, participants completed GCBM training, CBM training, or CBM control tasks depending on their assigned condition. Participants also completed the same IMS, demographic questions, and attention check questions as in Study 1 (see Study 1 methods for details).

Statistical Analysis

We used box plots to identify and remove outliers (i.e., data points that fall 1.5 times above or below the interquartile range). Data were assessed for normality using skewness and kurtosis statistics and were found to meet the assumptions of normality.

To replicate the findings of Study 1 and perform a manipulation check, we conducted a linear regression analysis using SPSS 28 software. This analysis compared post-training balance points between the GCBM condition and other conditions (CBM training and CBM control), as well as all other pairwise combinations of conditions. We adjusted for baseline balance point and reported adjusted and unadjusted models. To assess the effects of training on mood scores, we employed a mixed-design ANOVA. This analysis included a between-subjects factor with three levels: GCBM training, CBM training, and CBM control, and a within-subjects factor with two levels: pre-training and post-training IMS scores. We looked at the interaction effect group and time, which assessed whether the change in mood scores from pre-training to post-training varied across different groups.

We ran linear regression analysis using SPSS 28 software as a planned comparison to compare post-training IMS scores in the CBM and GCBM conditions (the primary outcome in our protocol), and additionally all other pairwise combinations of conditions as post hoc tests. We adjusted for baseline mood, age and gender, and reported adjusted and unadjusted models.

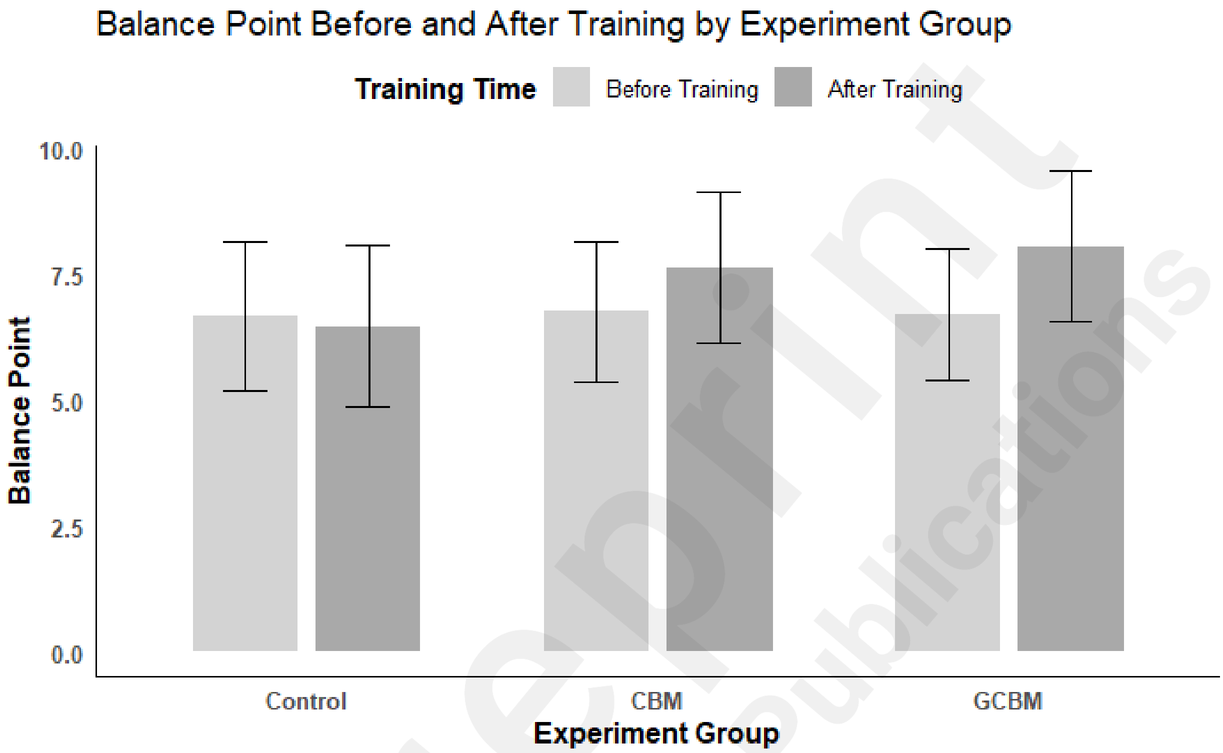
Results

We collected data from 927 participants. Seven of the participants did not complete the task. We removed 4 outliers that fell 1.5 times above or below the interquartile range. Of the remaining 916 participants, 55.1% were women (505 women and 392 men) and 19 participants did not state their gender. The mean age was 25.46. 76% of the participants were White, 11.2% were Asian, 6.6% were Black/African/Caribbean, 4.9% were Mixed/Multiple Ethnic Groups, 0.7% chose 'other' as an option.

Balance points

To assess the effect of training on emotion recognition bias, we examined participants' balance points pre- and post-training. Both CBM and GCBM training showed positive changes after training indicating that participants in both conditions categorized more ambiguous faces as 'happy' after training while the control condition showed no meaningful change (see Figure 4). On average, participants in CBM training showed a 0.87 point increase, while those in GCBM training demonstrated a 1.35 point increase.

Figure 4:
Graph for pre and post-training balance points for CBM, GCBM and control conditions. The graph shows that both CBM and GCBM training positively shifted participants' balance points. Higher balance points indicate participants categorised more faces as happy which suggests less negative bias when interpreting ambiguous emotional facial expressions.



We conducted exploratory, stratified linear regressions to compare post-training balance points of CBM and GCBM training with each other and the control group. The results showed that both CBM and GCBM training groups had improved post-training balance points compared to control group (B = -0.55, 95% CI [-0.64, -0.45], *P* < .001; B = -1.57, 95% CI [-1.76, -1.38], *P* < .001, respectively) Also, there is evidence that GCBM training induced a larger training effect than CBM, (B = .48, 95% CI [.35, .61], *P* < .001). (Group is coded as CBM = 1, GCBM = 2, and control = 3.; see supplementary materials Table T2).

Mood Outcomes

To assess the effect of training on immediate mood, we examined participants' post-training IMS scores. Participants in all conditions showed improved mood after the training. Control group had a 3.63-point improvement, CBM group had a 5.35-point improvement, and GCBM group had a 7.01-point improvement on average (See Table 1). To evaluate the effect of cognitive bias training on immediate mood a mixed method ANOVA with IMS as the outcome, time (pre-training/post-training) as a within-subjects factor, and group (CBM, GCBM, and control) as a between-subjects factor was performed. The ANOVA results indicated that there is evidence for an interaction effect between time (pre-post-training IMS) and group (CBM, GCBM, and control), $F(2,913) = 4.36$, $P = .01$, partial $\eta 2 = .01$.

Table 1:

Descriptive statistics for pre and post-training IMS scores of CBM, GCBM and control groups. Higher IMS scores indicate better mood.

	CBM			**GCBM**			**Control**		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Pre-training IMS score	96.39	25.32	400	98.12	27.27	397	95.50	26.54	119
Post-training IMS score	101.74	26.43	400	105.13	28.11	397	99.13	27.91	119

To investigate this interaction effect, we ran stratified linear regressions to assess the effect of CBM, GCBM, and control groups on post-training IMS scores. The results indicated no substantial evidence that participants in the CBM training experienced improved immediate mood compared to the control group ($P = .13$). However, participants in the GCBM training group reported improved immediate mood compared to the control group (B = -3.64, 95% CI [-6.02, -1.25], $P = .003$). Additionally, there is weak evidence that GCBM leads to more positive changes in participants' moods compared to CBM (B = 1.73, 95% CI [.05, 3.41], $P = .044$; our primary prespecified outcome). These effects persisted after adjusting for pre-training IMS scores, age, and gender (see supplementary materials Table T3).

Discussion

In this study, our objective was to assess the effectiveness of a new GCBM task to change judgements of emotional facial expressions and the immediate mood of participants. The results of Study 1 demonstrated that GCBM training positively changed the participants' responses to emotional faces. These findings suggest that GCBM is more effective than the earlier CBM task at changing participants' judgements of emotional expression. The results of Study 2 provided some evidence that GCBM improved immediate mood more than the control and CBM groups.

Study 2 showed that the difference between pre and post-training balance points was greater in both CBM and GCBM groups compared to control. This indicates that both training methods generated a positive shift in the responses to emotional facial expressions, in comparison to the control (no training) condition. Also, all three groups demonstrated an improvement in IMS after the training. However, participants in the GCBM group showed greater immediate mood improvement compared to those in the control and CBM conditions. There was no statistical evidence for a difference between the CBM and control groups in terms of immediate mood improvement. These results suggest that GCBM training is successful in both modifying responses to emotional facial expressions and enhancing participants' immediate mood, above and beyond the (unusual, in our previous experience) positive effects of financial compensation for participation.

Participants in the GCBM group showed a greater positive shift in their responses to emotional faces compared to the CBM group. This result suggests that gamification of the task increased engagement with the cognitive target of the intervention. This outcome aligns with the rationale behind the CBM training which suggests that changing people`s perspective toward ambiguous facial expressions can improve their mood and potentially improve the symptoms of depression [10]. The results might suggest that greater improvement in emotion perception was associated with better improvement in immediate mood. On the other hand, greater improvement in immediate mood in the GCBM group might be solely the result of the absence of the negative effect of feedback in CBM as we predicted.

While some previous studies have shown mood improvement after multiple sessions of CBM training using the outlined method, most studies have not demonstrated significant evidence of improvement [8,25]. Results from a meta-analysis revealed that CBM has no overall positive effect on mood. However, the relationship between CBM and mood is mediated by the reduction in emotion recognition bias after training [9]. These results suggest that some therapeutic benefits of CBM may be masked or attenuated by the negative feedback in the training condition. GCBM was designed to address this issue by changing the delivery of feedback. Given that GCBM has been shown to reduce negative emotion recognition bias more effectively than CBM, it may be more effective when administered through multiple training sessions for longer-term mood improvement. Future studies should investigate the long-term effects of multiple GCBM training sessions on mood, as changes in mood related to depression are typically observed over an extended period [2].

One of the limitations of this study is that we only tested participants between the ages of 18 and 30 years old. This decision was based on previous research suggesting that younger participants tend to benefit more from this emotion recognition CBM task [8].
In this study, our primary objective was to gain a clear understanding of the effectiveness of gamifying this CBM task. However, further research is necessary to comprehensively explore the differences between younger and older individuals in terms of their response to this CBM intervention. Another limitation of this study is that we did not examine the improvement of depressive symptoms; we only assessed the immediate mood of the participants. The IMS asks participants how they are feeling at the moment. However, previous CBM studies have used questionnaires that assess depressive symptoms. Although immediate mood can be an indicator of depressive symptoms[23], the effect of GCBM on depressive symptoms still needs further investigation.

An additional limitation of the study is the absence of a control group where participants played a game unrelated to emotion recognition training. The only control group in Study 2 was the CBM control condition, which is similar to CBM training but without the training component. This means we did not compare the impact of simply playing a game versus the impact of GCBM training on immediate mood. It is possible that GCBM influences immediate mood through the enjoyable aspects of playing a game. Future studies should test the effect of GCBM against similar game control conditions.

Study 2 provided evidence suggesting that GCBM improved people`s immediate mood compared to the control group. This indicates that this GCBM intervention may be acceptable to those suffering from mood disorders should they be demonstrated to be effective in reducing depression in further studies. Importantly, compared to CBM training, GCBM showed a more pronounced shift in their responses to emotional faces after training, and their immediate mood improved to a greater extent. These results hold promise and indicate potential benefits for the clinically depressed population. Given the importance of developing remote and cost-effective interventions for depression, future studies should investigate the long-term effects of GCBM on depression symptoms and recruit participants diagnosed with depression, as they constitute the actual target group for GCBM.

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Conflict of Interests

I.P.-V. is a director of Jericoe Ltd, which develops software for assessing and modifying emotion perception. Authors RK and AA declare no conflicts of interest.

Abbreviations

BP: balance point
CBM: Cognitive Bias Modification
GCBM Gamified Cognitive Bias Modification
IMS: Immediate Mood Scaler

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Supplementary Materials

S1: Scoring System for GCBM

The balance point (for details, see Study 1) was calculated in the baseline block for each participant before training and used as their baseline score. In the GCBM training condition, participants were trained to shift their balance points by 2 points, enabling them to categorize 2 more faces as happy. After the baseline block participants started training blocks and were asked to choose happy or sad for each face. Incorrect answers for these faces resulted in zero points, while correct answers earned points based on the ambiguity of the faces. Faces closest to the participant's balance point (the most ambiguous one above and one below) were worth 15 points. The scoring equation used was: Score = Max Score – |Stimuli Level – Rounded Balance Point| where the maximum score was 15, stimuli level ranged from 0 to 15 (0 for happy, 15 for sad, with morphed faces in between), and the Rounded Balance Point was the participant's balance point rounded to the nearest integer. For example, if a participant in the training condition gets a baseline balance point is 7 we train them to increase their balance point to 9. In this case, when they see the Stimuli Level 8 and find the correct answer they receive 14 points. This method allowed each participant to earn personalized points based on their specific balance point.

Protocol Deviations:

S2: Adding a control condition post hoc.

In the protocol for Study 2, we stated that we would compare the GCBM training and CBM training conditions only, without including any control groups, given the previous studies on CBM did not demonstrate pronounced mood enhancement after training (see Kuruoglu et al., 2024). Therefore, we collected data for CBM training and GCBM training conditions (400 participants for each group). We expected to find an improved mood in the GCBM group, while the mood in the CBM group would remain similar. Nonetheless, the results of Study 2 showed that both the GCBM and CBM groups' moods improved after the training. Following these findings, our aim was to investigate whether these results stemmed solely from the training effects or were influenced by other factors, such as compensation provided for study participation. We hypothesised that the differences between pre-training and post-training mood scores can be attributed to the combined effects of compensation and GCBM/CBM training. To test this hypothesis, we collected data from a CBM training control group which was compensated but did not attempt to change emotion judgments to assess the effect of financial compensation alone on mood. Afterwards, we proceeded to compare the three groups: CBM training, GCBM training, and CBM control group, to allow us to estimate the role that compensation alone may play in our results. We hypothesized GCBM training group would show significantly higher post-training mood scores when compared to the control group.

S3: Sample size determination for the control group

We conducted an additional power calculation for the control group based on the effect sizes of the differences between the pre and post-training Immediate Mood Scaler (IMS) scores in Study 2. The effect sizes are moderate for both groups, with d = 0.58 for GCBM and d = 0.45 for CBM. An a priori power analysis was performed using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007). Our calculations indicated that a sample size of 115 participants in the control group would provide us with the ability to detect an effect size of d = 0.45 with a power of 99%. We recruited 120 participants to allow for participants failing attention checks or not completing the study. We ran the CBM training control condition on this group of 120 participants to investigate whether the differences observed between pre and post-training mood scores are indeed attributable to the effects of CBM and GCBM training.

Supplementary Materials Tables

Table T1:

Regression results for balance points. Group is coded as CBM = 1, GCBM = 2, and control = 3.

Model		Unstandardized Coefficients			Standardized Coefficients	
		B	95% CI LL	95% CI UL	β	*p*
1	Group (CBM, control)	-.55	-.64	-.45	-.29	<.001
	Pre-training BP	.84	.78	.90	.74	<.001
2	Group (GCBM, control)	-1.57	-1.76	-1.38	-.40	<.001
	Pre-training BP	.91	.85	.97	.73	<.001
3	Group (CBM, GCBM)	.48	.35	.61	.16	<.001
	Pre-training BP	.87	.82	.92	.78	<.001

Note: The outcome is the post-training balance point. Model 1: Comparison of the effect of CBM and control on balance points. Model 2: Comparison of the effect of GCBM and control on balance points. Model 3: Comparison of the effect of CBM and GCBM on balance points.

Table T2:
The effect of Gamified Cognitive Bias Modification on the post-training balance point. Group is coded as control = 1 and intervention = 2.

Model		Unstandardized Coefficients			Standardized Coefficients	
		B	**95% CI LL**	**95% CI UL**	**β**	***p***
1	**Group (control and intervention)**	1.77	.61	2.93	.38	.004
2	**Group (control and intervention)**	1.73	1.21	2.25	.37	<.001
	Pre-training balance point	1.23	1.07	1.40	.83	<.001
3	**Group (control and intervention)**	1.73	1.24	2.22	.37	<.001
	Pre-training balance point	1.16	.99	1.32	.78	<.001
	Gender	-.20	-.71	.32	-.04	.445
	Age	.03	.01	.05	.17	.004

Note: The outcome is the post-training balance point. Model 1 is unadjusted which is the effect of the different groups on the post-training balance point. Model 2 is adjusted for the pre-training balance point. Model 3 is additionally adjusted for age and gender.

Table T3:

Regression results for mood outcome (IMS). Group is coded as CBM = 1, GCBM = 2, and control = 3. Gender coded as Women =1 Men =2.

		Unstandardized Coefficients			Standardized Coefficients	
Model		**B**	**95% CI LL**	**95% CI UL**	**β**	***p***
1	**Group (CBM, control)**	-.97	-2.21	.27	-.03	.125
	Pre-training IMS score	.93	.89	.97	.90	<.001
2	**Group (CBM, control)**	-1.00	-2.23	.23	-.03	.112
	Pre-training IMS score	.93	.89	.97	.89	<.001
	Age	-.25	-.59	.08	-.03	.135
	Gender	2.36	.25	4.46	.04	.028
3	**Group (GCBM, control)**	-3.64	-6.02	-1.25	-.05	.003
	Pre-training IMS score	.94	.91	.98	.91	<.001
4	**Group (GCBM, control)**	-3.64	-6.02	-1.25	-.05	.003
	Pre-training IMS score	.94	.91	.98	.91	<.001
	Age	-.03	-.34	.28	.00	.860
	Gender	.21	-1.82	2.24	.00	.838
5	**Group (CBM, GCBM)**	1.73	.05	3.41	.03	.044
	Pre-training IMS score	.93	.90	.96	.90	<.001
6	**Group (CBM, GCBM)**	1.69	.02	3.37	.03	.048
	Pre-training IMS score	.93	.90	.96	.90	<.001
	Age	-.19	-.45	.07	-.02	.147
	Gender	1.60	-.09	3.29	.03	.064

Note: The outcome is the post-training IMS score. Model 1: Comparison of the effect of CBM and control on mood. Model 2: Comparison of the effect of CBM and control on mood adjusted for age and gender Model 3: Comparison of the effect of GCBM and control on mood. Model 4: Comparison of the effect of CBM and control on mood adjusted for age and gender. Model 5: Comparison of the effect of CBM and GCBM on mood. Model 6: Comparison of the effect of CBM and GCBM on mood. adjusted for age and gender.