Effects of positive interpretive bias modification in highly anxious individuals

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ABSTRACT

Over the past 20 years evidence has accumulated that individuals suffering from anxiety tend to interpret ambiguous information as threatening. Considering the causal role of this interpretive bias in anxiety, it was recently established that modifying interpretive biases influences anxiety. This suggests that anxiety can be clinically treated by directly targeting this interpretive bias. The present study was designed to modify a negative interpretive bias in highly anxious individuals, and subsequently assess the hypothesized beneficial effects on clinical measures. High trait-anxious participants were randomly assigned to one of two conditions: a positive interpretational Cognitive Bias Modification (CBM-I) or a control condition (n = 2 × 17). The program was offered online for eight consecutive days. Upon completing the program, participants who had followed positive CBM-I were less state and trait-anxious compared to the control group. Additionally, positively trained participants scored lower on a measure of general psychopathology (SCL-90). No effects were observed on social anxiety and stress vulnerability. The mixed pattern of findings renders them rather inconclusive, leaving interpretations of the potential therapeutic merits of CBM-I open for future research.

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1. Introduction

There is overwhelming evidence that anxiety is associated with a maladaptive tendency to interpret ambiguous information in a threatening way (Amir, Foa, & Coles, 1998; Eysenck, Mogg, May, Richards, & Mathews, 1991; MacLeod & Cohen, 1993). The studies that yield these conclusions all have cross-sectional designs: anxious participants are compared to non-anxious control groups. As a result, a shortcoming of these studies is that they shed no light on the issue of causality. Does anxiety cause the interpretive bias? Or does the interpretive bias contribute to anxiety? Are anxiety and the interpretive bias mutually reinforcing and/or is a third variable driving both anxiety and the interpretive bias?

In order to resolve the question of causality, Mathews and Mackintosh (2000) developed a program designed to modify interpretive bias: Cognitive Bias Modification of Interpretations (CBM-I). Biases were modified by presenting a series of ambiguous social stories, each ending in a word fragment, to non-anxious participants (individuals with a mid range level of anxiety). Correct resolution of the fragment disambiguated the story either positively or negatively, depending on the assigned modification condition. Subsequently, Mathews and Mackintosh tested whether the modification of the interpretive bias resulted in a corresponding change in anxiety. A “recognition test” (see below) confirmed that CBM-I effectively induced an interpretive bias. Negatively trained participants interpreted new ambiguous information in a threatening way. Conversely, positively trained participants made more non-threatening interpretations. More importantly, CBM-I effected congruent changes in anxiety. Positively trained participants became less anxious, while negatively trained participants became more anxious. The main findings observed in this study were replicated various times (Mackintosh, Mathews, Yiend, Ridgeway, & Cook, 2006; Salemink, van den Hout, & Kindt, 2007b; Yiend, Mackintosh, & Mathews, 2005). Consequently, the data indicate that the interpretive bias plays a causal role in anxiety and that it can be modified through training.

All of the abovementioned studies trained individuals with a mean level of anxiety. It has thus been established that the interpretive bias is trainable and that it affects anxiety. Therefore, it seems that there would be clinical relevance in training individuals with high anxiety levels, such as patients suffering from an anxiety disorder, to interpret information positively.1 An important first step was taken by Mathews, Ridgeway, Cook, and Yiend (2007), who performed a positive CBM-I study in an analogue sample of highly anxious participants with clinical levels of anxiety, though no formal paper is (yet) available.

1 Amir and Beard (2007, July) already performed a CBM program using participants with clinical levels of anxiety, though no formal paper is (yet) available.
anxious community volunteers \((n = 39)\). Half of the participants received training to interpret information in a positive way, while the other half was assigned to a test–retest control condition. Individuals in the positive group received four CBM-I sessions over a two-week period. Each session consisted of 100 stories. Along the course of the sessions, the stories became more positive; i.e. the first session involved stories with non-negative interpretations, while in later sessions the interpretations of these 100 stories became gradually more positive. Pre- and post-measurement of the interpretive bias showed that the positive CBM-I was successful: positive interpretations increased, while negative interpretations decreased. More importantly, the positive CBM-I resulted in a significant reduction in trait anxiety scores. Thus, this evidence supports the proposed beneficial effects of positive CBM-I on trait anxiety. No effects on state anxiety were found.

While results from the Mathews et al. study (2007) are encouraging, several issues demand clarification. First of all, the control group did not receive any training and was only tested twice. Consequently, it is unclear whether reported results are caused by the intervention or are due to mere exposure to valenced material, demand characteristics, etc. To rid the results of this ambiguity, a control training condition is warranted. Second, the measured effects on trait anxiety were moderate. While no effects were found on state anxiety, the changes observed on trait anxiety were relatively small (a decrease of 4.2 on the trait version of State-Trait Anxiety Inventory, STAI, Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). In order to ensure the CBM-I’s clinical relevance, the effects should be larger. In Mathews et al.’s format, individuals were succumbed to a mere four training sessions in a two-week period. In other words, participants had more training-free days than training days. Participants may benefit from an intensified CBM-I, by having, for example, more training than training-free days, and/or by increasing the total number of different trials and sessions.

The present experiment was designed with two objectives in mind: to assess the robustness of previous findings, considering the effects of induced positive interpretations on the reduction of anxiety, and to optimize the CBM-I program. First of all, we ensured an intensive CBM-I program by developing an eight-day program, in which participants were not allowed to skip a single day. Second, we increased the total number of new trials. Each day consisted of 104 new trials. The total number of trials amounted to 832 (while four versions of 100 trials were presented in Mathews et al., 2007). Third, we developed a control training condition. Participants in this condition also received an eight-day program, but now half of the stories ended positively while the other half ended negatively. Thus, these participants were not trained to interpret information either positively or negatively, but were simply engaged in an intensive program for several days. A fourth aspect is that we decided to train participants in their own environment. An internet CBM-I program was developed that could be accessed at home. State and trait anxiety were measured by the same means as in the Mathews et al. study. However, to further explore the range of effects of an induced positive interpretive bias, we also assessed the effects on general psychopathology (SCL-90: Arrindell & Ettema, 1986; Derogatis, 1977) and social anxiety (Fear of Negative Evaluation, FNE: Watson & Friend, 1969). Furthermore, we examined whether interpretive bias causally modulates emotional vulnerability (the degree to which a stressor serves to aggravate a negative mood state). Therefore, participants had to perform a stress task after CBM-I to assess the degree to which participants differed in terms of their anxiety reactivity.

In sum, we designed the current study to examine whether reductions in negative interpretive bias in sub-clinically anxious individuals lead to congruent beneficial effects on mood. Pre-selected high trait-anxious individuals with higher than average negative interpretations received either the eight-day experimental condition of CBM-I (positive CBM-I) or the eight-day control condition. The following hypotheses were formulated, all of which were directional. The first hypothesis predicted that CBM-I would effectively induce positive interpretations in the experimental group when compared to the control group. Assuming that the interpretive bias modification would be successful, the second hypothesis stated that the positively trained group would become less anxious than the control group. Finally, it was also predicted that the general psychopathology scores of the positively trained group would decrease. Concerning the effects on emotional vulnerability, a hypothesis was formulated predicting that the positively trained group would be less reactive to stressors in comparison to the control group.

2. Method

2.1. Participants

In order to obtain a group of high trait-anxious participants with a negative interpretive style, we had to establish criteria for both high anxiety and negative interpretive bias. Following Yiend et al.’s example (2005), a score of 45 or higher on the trait version of the STAI (Spielberger et al., 1983) was set as a criterion for high anxiety. This represented the top 20% of a sample of 321 students who filled out the STAI trait questionnaire following a lecture (M = 47.4, SD = 8.7). To find a criterion for interpreting information negatively, we first assessed how students interpreted ambiguous information. A random sample of 40 students from the general student population completed the closed questions version of the Ambiguous Social Situation Interpretation Questionnaire (ASSIQ: Stopa & Clark, 2000) (see Section 2.2). The mean score for this sample of students was 1.56 (SD = 0.4), we therefore considered a score \(\geq 1.57\) higher than average for negative interpreting. This was the second criterion for inclusion. The combined criteria resulted in a sample of 36 highly trait-anxious participants who had above average scores on the negative interpretation of ambiguous information. During the experiment, the data of two participants had to be removed because they skipped a training day, yielding a final sample of 34. Of this sample six were male and their mean age was 21.3 years (SD = 2.1). Before the start of CBM-I, participants in the positive and the control group did not differ significantly for scores on the ASSIQ, \(t(32) = -1.58\), STAI state, \(t(32) = -0.31\), STAI trait, \(t(32) = -0.20\), and SCL-90, \(t(32) = -1.51\). The groups differed on the FNE scores, \(t(32) = -2.48, p < .05\), participants in the positive CBM-I group had higher scores than participants in the control condition (respectively, 36.4, SD = 8.3 vs. 28.3, SD = 10.5). As a next step, pre-CBM-I FNE scores were examined in relation to changes in crucial other dependent mood variables. Pre-FNE scores were significantly related to change in FNE, \(F(1, 31) = 5.44, p < .05, \eta^2_p = .15\). Those statistical analyses are, therefore, performed with pre-FNE scores as a covariate. As pre-FNE scores were not significantly related to other dependent mood questionnaires, \(F < 1.1\), those analyses were conducted without correction for pre-FNE scores. All participants received course credits and a financial reimbursement.

2.2. Materials

2.2.1. CBM-I stimuli

To modify interpretive bias, participants were trained for 8 h: 1 h a day on eight consecutive days. Participants received 832 social stories in total, of which 104 were translated stories used by Mathews and Mackintosh (2000). The rest were designed
exclusively for the present study. Every day, participants received 104 stories, presented in eight blocks with optional rests between each block. Each block contained (1) eight modification stories, (2) three filler stories, and (3) two probes, all presented in random order.

The ‘modification stories’ consisted of three lines that were ambiguous in terms of valence. The story’s meaning would be left ambiguous up to the final sentence, where a word fragment disambiguated the story. In the positive condition the stories would have a positive outcome. In the control condition half of the stories would have a positive and half a negative outcome. Every word fragment had only one meaningful solution and participants were asked to complete the fragments as quickly as possible. A comprehension question with relevant feedback appeared on the screen to reinforce the interpretation imposed by the word fragment. Example modification stories with the completed word fragments for each condition (appearing in parentheses) are presented here:

You asked a lot of questions during lecture because you didn’t understand the subject and tried to grasp it. The other students seemed to find it difficult too. They listened with . . . to all your questions. app-—tion (appreciation)/ir—tion (irritation)

The story was immediately followed by a comprehension question:

Did the other students find you annoying?

The ‘filler stories’ had no emotional content, nor did they contain ambiguity. They were inserted to make the CBM-I less obvious:

You arrange to meet a friend at your local pub one evening. As you arrive, you cannot help noticing that the sign in front has been pa-n-—d (painted)

Has your pub changed its appearance?

The ‘probe stories’ were similar to the modification stories, but they had a fixed positive and negative valence, irrespective of the modification condition. Thus both groups received the same word fragments as probes. These probes were inserted to measure the speed of resolving word fragments of positive and negative valence across the training phase. Effective training was obtained when positively trained participants were faster at solving positive word fragments and slower at solving negative word fragments compared to the control group.

2.2.2. Recognition test stimuli: test of CBM-I effects on interpretive bias

Upon completing the last block on the last day of training, participants received a recognition test to assess their interpretation style (translation of Mathews and Mackintosh’s [2000] recognition task). Participants had to resolve ten new ambiguous test items, much as they did for the CBM-I items. This time, however, every story had a title and was presented in a uniquely identifiable context, following Mathews and Mackintosh. To maximize the resemblance of these items to those presented in the modification condition, participants were required to solve a word fragment and to answer a comprehension question. Yet this time the valence of the story remained ambiguous. An example of these ambiguous test items is presented here (with the completed word fragment in parentheses):

The job interview
You see a job advertised that you’d really like. You apply and are invited to an interview, where you answer the questions as well as you can. Reflecting later, you think that the quality of your answers decided the ou-—om-— (outcome)

The comprehension question immediately followed:

Did you think about your answers later?

In the second part of the recognition test participants saw the title of the ambiguous story, together with four versions of the final sentence. These sentences represented (a) a possible positive interpretation, (b) a possible negative interpretation, (c) a positive foil sentence, and (d) a negative foil sentence. Participants rated each sentence for its similarity in meaning to the original story using a 4-point scale, ranging from 1 (very different in meaning) to 4 (very similar in meaning). The four corresponding sentences of the ambiguous test example above are presented here:

a) You think it must have been your clear answers that got you the job.

b) Reflecting later, you realize that your poor answers lost you the job.

c) Reflecting later, you think it was a good thing you did not take the job.

d) You think that your appearance must have made a bad impression.

It was predicted that positively trained participants would give more positive and less negative interpretations compared to the control trained participants.

2.2.3. ASSIQ

Participants had to fill in the closed-ended version of the ASSIQ (Stopa & Clark, 2000) before and after undergoing CBM-I. Participants received short descriptions of ambiguous social (14 items) and control situations (10 items), followed by three alternative, experimenter-provided explanations. One explanation was always negative, one was always neutral and the third was positive or neutral. Participants rank-ordered all three interpretations in terms of the extent to which “they would be most likely to come to your mind if you found yourself in a similar situation.” When a negative social explanation was ranked first, second, or third, a score of 3, 2, or 1 was given respectively. Thus, higher scores reflected more negative bias in information processing.

2.2.4. Measurements of mood and psychopathology

Participants completed four questionnaires during pre- and post-test periods in the laboratory. We presented the participants with the state and trait scales of the State-Trait Anxiety Inventory (STAI-ST, Spielberger et al., 1983) to measure state and trait anxiety. Both scales contain 20 items. We used the 12-item Fear of Negative Evaluation questionnaire (FNE, Watson & Friend, 1969) to assess social anxiety and the Symptom Check List (SCL-90, Arrindell & Ettema, 1986; Derogatis, 1977) to assess general psychopathology.

To assess participants’ daily mood and arousal state during CBM-I, each session started with a computerized pleasure and arousal subscale of the Self-Assessment Manikin (SAM). The SAM pleasure subscale ranges from a smiling, happy figure (score 1) to a frowning, unhappy figure (score 9). The arousal subscale ranges from an excited figure (score 1) to a relaxed figure (score 9) (Hodes, Cook, & Lang, 1985; Lang, 1980).

2.2.5. Stress task

During the post-test in the laboratory, participants were exposed to an anagram stress task to elicit hypothesized variations in stress vulnerability affected by CBM-I. The task was adapted
from the anagram stress task used by MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002) and is capable of inducing stress. Participants were told that the task would be difficult, but that intelligent participants like students usually perform well. They were also told that a meeting with other students would take place afterwards, to compare personal performance to the performance of others. Participants saw 15 anagrams on the computer screen, one at a time. The objective was to solve as many anagrams as possible by writing down the correct words on a response sheet and pressing the space bar to go to the next one. When no response was detected in 20 s, the computer signaled that the participant should respond faster. Half of the anagrams were extremely difficult and consisted of at least 13 letters. The other half ranged from simple to quite difficult (4–9 letters).

Participants completed two computerized visual analogue mood scales (VAS) before and after the stress task to measure their emotional reactions to it. One scale assessed anxiety and was labeled at opposite ends with the words happy and relaxed and the other scale assessed depression and was labeled at opposite ends with happy and depressed (MacLeod et al., 2002). Both scales consisted of a 15-cm horizontal line. Participants scored their mood by selecting a location on the line with a mouse click. Each scale completion yielded a score ranging from 0 to 100, with a higher score indicating a higher level of negative mood.

At the very end of the experiment participants were informed that there was, in fact, no meeting in which they could discuss their experiences. Participants were informed that payment would only be received if the series of sessions were completed without fail on eight consecutive days. The experimenter checked this every day in the online database. Participants gave written informed consent. They completed four computer-delivered questionnaires in separate cabins. The computer-program started with the state and trait versions of the STAI, followed by the FNE and the SCL-90. This session lasted for approximately 30 min.

Each home-session started with some instructions to try to ensure a quiet and undisturbed test environment. Then the mood and arousal subscales of the SAM were presented, after which CBM-I commenced. Reaction times and accuracy scores for solving word fragments in probe stories were assessed. Answers to the comprehension questions were also recorded. The duration of a session was approximately 1 h. After the last block of training on the eighth day, participants received a recognition task to test for the predicted effects on interpretive bias.

During the 1-h post-test in the laboratory, participants were once again asked to fill-in the four questionnaires on a computer together with the ASSIQ. Then a stress task was administered with a pre- and post-test for mood (VAS). Finally, participants completed the exit questionnaire and were debriefed.

3. Results

3.1. Effectiveness of CBM-I in changing interpretations

3.1.1. Reaction times to probes

To test effectiveness of CBM-I in changing interpretive style, reaction times were analyzed with a three-way mixed model ANOVA with CBM-I group (positive vs. control) as the between-subjects factor and probe (positive vs. negative) and time (first vs. second half of CBM-I) as the within-subject factors. The factor time was added to examine the development of CBM-I effects on interpretations. Trials where an incorrect response was given, were omitted from the analysis. There was a main effect of time, $F(1, 32) = 16.61, p < .001$, indicating that faster responses were given in the second half of CBM-I. There was also a main effect of probe, $F(1, 32) = 127.27, p < .001$, $\eta^2 = .80$, indicating that faster responses were given to positive probes. More importantly, the
predicted Group × Probe interaction effect was significant, \(F(1, 32) = 9.72, p < .01, \eta^2_p = .23\), confirming the effectiveness of CBM-I. While the control group did not react differently to negative and positive probes (962 ms, SD = 325 and 945 ms, SD = 323, \(t(16) = -1.53\)), participants who had previously been exposed to the positive CBM-I displayed a marked slowing in reacting to negative (1071 ms, SD = 232) as compared to positive probes (943 ms, SD = 188, \(t(16) = -3.79, p < .01\), see Fig. 2).

To examine efficacy of the newly developed scenarios, a mixed model ANOVA was conducted with group as the between-subjects factor and probe and scenario type (original vs. new) as the within-subjects factors. The main effect of scenario type was not significant, \(F(1, 32) = 0.02\) and no interaction effects were found involving group, Fs < 1.4.

### 3.1.2. Recognition ratings

The second test of induced interpretations was the recognition test, which was to be completed at home after CBM-I. Due to technical problems, seven participants completed this recognition test the next day in the laboratory (four positively trained and three control trained participants). There were no significant differences between this subgroup and the participants who completed the recognition task at home in age, sex distribution, and scores on the various questionnaires. A mixed model ANOVA with group as the between-subjects factor and valence (positive vs. negative) and target (possible interpretation vs. foil sentence) as the within-subjects factors was performed first with these seven participants and later without them. The first analysis revealed a main effect of valence, \(F(1, 32) = 6.04, p < .05\), \(\eta^2_p = .16\), with positive sentences being endorsed more than negative sentences, and of target, \(F(1, 32) = 112.94, p < .001\), \(\eta^2_p = .78\), indicating greater endorsement of probable interpretations than of foils. The most pertinent analysis with respect to our manipulation was the three-way interaction effect of Group × Valence × Target. This effect failed to reach significance, \(F(1, 32) = 1.44\).

Performing the analysis with the smaller group of 27 participants yielded significant main effects of valence, \(F(1, 25) = 14.46, p < .001\), \(\eta^2_p = .37\), and target, \(F(1, 25) = 304.31, p < .001\), \(\eta^2_p = .92\). Interestingly, the predicted three-way interaction effect of Group × Valence × Target was significant, \(F(1, 25) = 4.85, p < .05\), \(\eta^2_p = .16\). To decompose this interaction effect, we carried out separate analyses for probable interpretations and foil sentences. For the probable interpretations, a predicted Group × Valence interaction effect was significant when taking the directional nature of the hypothesis into account, \(F(1, 25) = 3.24, p < .05, \eta^2_p = .12\), which was absent for foils, \(F(1, 25) = .00\). Positively trained participants gave more positive interpretations than the control trained participants (3.2, SD = 0.3 vs. 2.9, SD = 0.5, \(t(25) = 2.10, p < .05\), see Fig. 3). Thus, when measured within a period of 24 h, participants had the tendency to interpret new ambiguous information with the valence they had been trained in. The statistical analyses of the mood questionnaires were conducted with and without those seven people. Since a similar pattern of results was obtained for both groups, results are reported for the total sample.

#### 3.1.3. Ambiguous Social Situations Interpretations Questionnaire

Presence and nature of the induced interpretive biases were also tested by analyzing the social items of the ASSIQ. A two-way ANOVA with group as the between-subjects factor and time (before and after CBM-I) as the within-subject factor revealed a main effect of time, \(F(1, 32) = 11.76, p < .01, \eta^2_p = .27\), representing a reduction in negative interpretations in both groups. The positive group scored 2.2 (SD = 0.3) before CBM-I and 1.9 (SD = 0.4) afterwards and the control group scored 2.0 (SD = 0.3) and 1.9 (SD = 0.4) respectively. The predicted Group × Time interaction effect was not significant, \(F(1, 32) = 1.77\).

### 3.2. Effects on mood and symptoms of psychopathology

#### 3.2.1. Daily mood and arousal level

Effects of CBM-I on changes in mood and arousal during CBM-I (SAM) were examined with a two-way mixed model ANOVA with group as the between-subjects factor and time (first and second half of CBM-I) as the within-subject factor. Concerning mood, there was a main effect of time, \(F(1, 32) = 4.61, p < .05, \eta^2_p = .13\), indicating that both groups felt more negative during the second part of CBM-I. Concerning arousal, the predicted Group × Time interaction effect was significant, \(F(1, 32) = 2.94, p < .05, \eta^2_p = .08\). While the participants in the control group got less relaxed (before 6.4, SD = 1.8 after 5.8, SD = 1.5), the positively trained participants remained relatively stable (before 5.4, SD = 1.7 after 5.6, SD = 1.7).

#### 3.2.2. State and trait anxiety

A 2 × 2 ANOVA on state anxiety revealed the predicted Group × Time interaction effect, \(F(1, 32) = 2.88, p < .05, \eta^2_p = .08\). That is, state anxiety increased for the control group (before 39.4, SD = 8.9 after 43.0, SD = 8.6), but not for the positively trained group (before 40.5, SD = 11.2 after 39.4, SD = 6.6).

For trait anxiety, a significant main effect of time was found, \(F(1, 32) = 5.93, p < .05, \eta^2_p = .16\) reflecting a decrease in trait anxiety scores. This analysis also revealed the predicted Group × Time interaction effect, \(F(1, 32) = 10.65, p < .01, \eta^2_p = .26\) confirming the effectiveness of CBM-I.

**Fig. 2.** Mean reaction times and SE (in ms) to solve probes during CBM-I.

**Fig. 3.** Mean recognition ratings and SE for possible interpretations with negative and positive valence depicted for each CBM-I condition.

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2 Directional testing in a 2 × 2 design is allowed, based on \(F(1, df) = t^2(df)\) (Dobson, 2002).

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interaction effect, $F(1, 32) = 3.51$, directional $p < .05$, $\eta^2_g = .10$. In line with our predictions there was a decrease of trait anxiety after positive CBM-I (before 50.0, SD = 9.0 after 47.3, SD = 9.6) compared to the control condition (before 49.5, SD = 6.0 after 49.1, SD = 7.1).

### 3.2.3. Fear of negative evaluations
A univariate analysis on the difference scores (post FNE–pre FNE), with pre-test FNE scores as a covariate, revealed a significant main effect for the covariate, $F(1, 31) = 5.44$, $p < .05$, $\eta^2_g = .15$. The predicted main effect of group was not significant, $F(1, 31) = 0.01$.

### 3.2.4. Symptoms Check List
A two-way ANOVA revealed a significant Group $\times$ Time interaction effect in the expected direction, $F(1, 32) = 3.19$, directional $p < .05$, $\eta^2_g = .09$. Compared to the control group (before 152.5, SD = 33 and after 153.9, SD = 36), the positively trained group tended to improve (before 175.9, SD = 55 after 159.8, SD = 23).

### 3.3. Stress vulnerability
On the stress task, a main effect of time was found for both anxiety and depression; anxiety: $F(1, 32) = 27.13$, $p < .001$, $\eta^2_g = .46$, depression: $F(1, 32) = 8.41$, $p < .01$, $\eta^2_g = .21$. No other effects were significant. While the stress task was capable of increasing both anxiety, from 30.3 (SD = 20.0) to 47.3 (SD = 22.7), and depression, from 40.2 (SD = 19.2) to 49.8 (SD = 20.6), it did not differentiate between both CBM-I groups.

### 3.4. Exit questionnaire
Results from the exit questionnaire revealed that only a small percentage of the participants (38%) indicated that they had an idea about the purpose of the study (positive CBM-I: n = 6, control condition: n = 7). Further inspection of their perceived study objectives showed that most of them (n = 11) thought it was an assessment study about ‘how you feel,’ ‘self-confidence,’ or ‘the perception of yourself and others.’ Only two participants were conscious of the modification. One of them (control condition) wrote ‘gradually adjusting the negative attribution style,’ while the other person (positive CBM-I condition) realized the association with mood: ‘improving self-confidence and attribution style.’ Removal of these two participants from the statistical analyses did not change the results.

### 4. Discussion
We adapted an interpretive bias modification procedure used in earlier laboratory research so that it could serve as a clinical intervention. Students who scored high on trait anxiety and had the tendency to negatively interpret ambiguous information were allocated to either a positive CBM-I internet training or a neutral internet training for eight days. Consistent with earlier findings (Mathews et al., 2007), CBM-I proved successful in modifying interpretations. Such modification of interpretive style was evident from training congruent changes to solve word-fragments, that is following positive CBM-I, participants were slower in reacting to negative word fragments as compared to responses to positive fragments. Furthermore, training congruent effects were observed on a post-training recognition test with new stimulus materials; positively trained participants interpreted information more positively than the control group. Results from the latter task were somewhat mixed, since effects were only observed when interpretive bias was measured directly following CBM-I and within its same context. Mathews et al. found straightforward effects on this recognition test. It must be noted, however, that the recognition test was also presented immediately after CBM-I and in the same context. This might suggest that the temporal and contextual generalizability of the modified interpretive bias is small. Nevertheless, earlier findings revealed 24-h effects on interpretation after undergoing CBM-I (Yiend et al., 2005), and Mackintosh et al. (2006) demonstrated that the interpretive bias effects survived changes in environmental context. However, the context switch in Mackintosh’s study was rather subtle, thus context dependency may still be a viable explanation. Furthermore, the fact that Mathews et al. had a graded presentation of the CBM-I materials might have influenced the results.

In the present study, no CBM-I effects were observed on the interpretive bias questionnaire. While the reaction time and recognition task have been used often to examine effects of CBM-I, the ASSIQ questionnaire has not. It might be that this questionnaire is not sensitive enough, or that self-reported interpretations are simply not affected by CBM-I. Moreover, lack of interpretive bias effects on the ASSIQ is consistent with earlier failure to find transfer (Salemink et al., 2007b; Salemink, van den Hout, & Kindt, in press). Robust effects of modified interpretive bias have been found when assessed by reaction times and scores on a recognition task (Mackintosh et al., 2006; Mathews & Mackintosh, 2000; Mathews et al., 2007; Salemink, van den Hout, & Kindt, 2007a, 2007b; Yiend et al., 2005). The reaction time task assesses how fast one is at the very task that is being trained. The recognition task is procedurally rather similar to the training task. That is, in both tasks the participant reads a short vignette of a hedonically ambiguous situation. The finding that changes in interpretive style are mainly observed in tests that are very similar to the training itself, while tests of a different procedure show less clear-cut training effects (Salemink et al., 2007b, in press), questions the validity of CBM-I. Clearly, the nature and generality of the induced changes in interpretative style warrant critical study.

Results as to effects of CBM-I on clinical measures were equivocal. While no differences between the CBM-I groups were found on a social anxiety measure (FNE), the positive CBM-I group had a medium effect on both state and trait anxiety and SCL-90 measured psychopathology. That is, SCL-90 measured levels of complaints remained the same in the control group and showed the predicted decline in the positively trained group. The same pattern was found in trait anxiety, which dropped 2.7 points in the positive CBM-I group (note that Mathews et al., 2007 observed a 4.2 decrease). It is possible that the observed change in this more enduring measure of anxiety is due to other processes, such as for example a trained positive response style. Participants in the positive CBM-I group might have learned to respond in a positive way to tests, while anxiety need not necessarily be changed. Note that a decrease in state anxiety in the positive CBM-I was absent, which renders this explanation less likely. Still, other mechanisms could underlie the effects and in future research it will be important to provide more objective measures of emotionality, such as psychophysiological assessments. Compared to trait anxiety, a different pattern was found for state anxiety; it remained stable in the positive group, while showing an unexpected increase for the control group. Possibly, the control condition may have provoked anxiety, since almost half (38%) of their stories had a negative valence. The control condition might inadvertently have led to negative interpretations. Yet, based on both theoretical arguments as well as new empirical data this seems rather implausible. Theoretically, the argument that a negative bias was induced in combination with the present pattern of equal responses to positive and negative interpretations after control CBM-I, requires the assumption of a positive bias before CBM-I. This contradicts the substantial body of data showing that, when compared to healthy individuals, highly anxious individuals have a higher negative interpretive bias (e.g. MacLeod & Cohen,
Given that it is, theoretically, highly unlikely that our participants had a positive bias before CBM-I, the next step was to test whether the control condition could unexpectedly have led to more negative interpretations. An experiment was conducted to test whether baseline scores on the recognition task for a group of highly anxious individuals differed from the scores of participants after control CBM-I. Results showed\(^1\) that the control CBM-I condition did not induce a negative interpretive style and that it functioned as a control condition, as intended.

A second explanation for increased scores for state anxiety in the control condition relates to the fact that CBM-I coincided with the period in which participants (all students) had to prepare for their final examinations. The increased scores on state anxiety and arousal in the control group (and the general increase in negative mood observed in both groups) may possibly reflect examination stress. The absence of such an increase in state anxiety and arousal in the positively trained group might be ascribed to a protective influence of the positive CBM-I. Thus, although the groups did not differ in reactions to laboratory stress, they may have differed in their response to naturally occurring stress, with the positively trained group being less affected than the control group.

For CBM-I to have clinical potential, it is crucial that the effects on clinical measures improve. Note that the study was designed as an analogue study, it is important for future research to replicate this study in a clinical population with anxiety disorders. Regarding the size of the effects, the present training already tried to boost the impact of CBM-I by increasing the number of different trials, the frequency of training, and by having participants train in their own homes. In the present study, participants were trained for eight days instead of only one (in original CBM-I studies) or four days (Mathews et al., 2007). Surprisingly, reaction time data shows no interaction effects with time. Even with a more fine-grained analysis (creating four blocks of two days instead of two blocks of four days), no effects emerged. A possible explanation is that effects of multiple training days will not be apparent due to ceiling effects, though they might appear in a challenge task where participants show no relapse into old interpretive bias habitats. In the present study, mood and various symptoms were only assessed directly before and after the eight-session treatment. The exact time course of clinical change due to CBM-I is, therefore, an empirical issue that awaits further investigation.

There may be other ways to optimize CBM-I. Adapting it to individual needs may improve the effectiveness. In the present training all participants received the same CBM-I materials with regards to social situations. They might benefit from tailored materials as those used in standard CBT protocols. The stories could be designed to include names of people in the participant's social circle, or they could refer to the participant's job, home situation and leisure activities. Furthermore, the pace of the training might be adjusted to someone's performance. Mathews et al. (2007) previously used stories that became more positive along the course of the sessions, this could be made performance dependent. For instance, when non-negative situations are solved quickly and accurately the transition to a next level could take place. If situations are not solved fast and without errors then that level could be prolonged. The transition from easy to difficult situations could be created along the same lines. CBM-I would then become interactive and would consistently match a participant's learning curve. Also, in the present study participants were unaware of the fact that their interpretation style was being modified. Hirsch, Krebs, and Hayes (2007) showed that effects of attentional CBM were increased for those participants who were informed about the modification. This might, thus, be an interesting option for further research. Finally, CBT is designed to reduce anxiety vulnerability through the modification of biased cognition. If automatization of the changed cognitions is a crucial aspect, then CBM-I seems promising because it directly intervenes with these processes. Targeting and optimizing automatization might be a fruitful direction to improve the effects.

Though much additional research is needed, it is tempting to speculate about possible clinical applications of CBM-I. For instance, we can expect that clinical patients should have even higher anxiety scores before undergoing CBM-I, yielding more room for improvement. We must, of course, consider the possibility that CBM-I does not reduce anxiety in patients, due to deeply embedded mechanisms that may be present in patients and not in highly trait-anxious individuals. Also, our CBM-I concerns the interpretation of social situations. We can, therefore, expect that social phobic patients would benefit most from it. And still the present study and that by Mathews et al.'s selected its participants only on trait anxiety and they improved. A next question could be, would the effects of CBM-I differ across different types of emotional problems?

Research on biased information processing in emotional disorders started some 20 years ago. Yet evidence of a causal relationship between biased information processing and the presence or worsening of emotional problems has started to accumulate only recently. This study has touched upon some of the clinical potentials of positive interpretive bias modification in groups of highly anxious individuals. Results are suggestive rather than conclusive, leaving ample room for exciting new research.

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**References**


