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**Abstract:** Cognitive Bias Modification (CBM) has been found to be effective in modifying information-processing biases and in reducing emotional reactivity to stress. Although modification of attentional and interpretation biases has frequently been studied, it is not clear whether memory bias can be manipulated through direct training of emotional recall. In two studies (in undergraduate students and in a community sample), memory bias for emotional verbal stimuli was trained with cued recall of either positive or negative words. We did not find evidence of malleability of memory bias for trained stimuli or induction of emotional reactivity to stress in either study. The training did, however, yield training-congruent mood effects and stimulated training-congruent incorrect recall in the community sample. Although we found no evidence for the direct modification of memory bias, the more global effects obtained with respect to retrieval of emotional information and mood are promising for CBM-memory studies in clinical samples.
Dear Professor Becker and Miss Woud,

Attached please find our revised manuscript #COTR-D-12-00185, “Can memory bias be modified? The effects of an explicit cued-recall training in two independent samples,” submitted to the CBM special issue of Cognitive Therapy and Research. We revised the manuscript according to your and the reviewers’ helpful suggestions. We were able to incorporate almost all of the minor concerns successfully. We describe in detail below how we addressed each of the concerns that you and the reviewers noted. For ease of communication, I have copied the comments into this letter (printed in italics).

Comments editor:
1. Please also briefly report the main statistics for the added (non-significant) results, e.g., page 9, analysis including selected participants or range correlation coefficients and p values, page 12.

Thank you for pointing this out. We have added the statistics to pages 9 and 12:
P. 9: “The effect of the training remained nonsignificant when selecting participants with a pre-existing negative memory bias (19 NMPs and 17 PMTs with pre-training correct-recall difference score <0, indicating more negative than positive recall), F(1,33) = 1.74, p = .20, f = .23, for Training x Time on correct recall, and F(1,33) = .36, p = .55, f = .11, on incorrect recall.”
P. 12 “Incorrect recall bias scores did not correlate significantly with any of the mood ratings, BDI-II total score, age, or sex (correlation coefficients between -.14 and .24 and p-values between .08 (for sex and incorrect recall post-training) and .95; see Table 1 for means and standard deviations).“

Thank you, we now refer to the Beard et al. review in the introduction:

“Studies applying CBM paradigms to healthy samples have shown that, in addition to manipulating biases, CBM also affects reactivity to subsequent stressors (Beard, Sawyer & Hofmann, 2012; MacLeod, Rutherford, Campbell, Ebsworthy & Holker, 2002; Mathews & Mackintosh, 2000; Wilson, MacLeod, Mathews & Rutherford, 2006).”

“In addition to altering stress reactivity in healthy individuals, CBM has been found to be effective in the treatment of anxiety (see review and meta-analyses: Beard, Sawyer & Hofmann, 2012; Hakatama et al., 2010; Hallion & Ruscio, 2011). In contrast, investigators examining CBM have focused far less frequently on depression (Beard, Sawyer & Hofmann, 2012; Hertel & Mathews, 2011).”

Reviewer #2:

1. (Page 4, Line 41-43) The way in which the authors operationalize specific versus global memory remains a bit unclear. It would be helpful to clarify that specific memory is related to learned stimuli, whereas global stimuli refer to any non-learned emotional stimuli recalled by the participant.

This section in the introduction has been adapted according to the reviewer’s suggestion:

“In order to examine how the training affected memory bias, we distinguished between specific and global memory bias. Here, specific memory is related to correct recall of learned stimuli, whereas global memory refers to (incorrect) recall of non-learned verbal emotional information.”

2. (Page 5, Line 28-29) Thank you for adding the sentence on the BDI-II. However, it would be helpful to know a bit more about the version of the measure you used. Has it been translated into Dutch? What are the cut-off scores you are using to determine that the mean scores in your sample were low? Also, it may be more appropriate to include this info within your Materials, Apparatus, and Procedure section than in your Participants section. Finally, you sometimes refer to the measure as the BDI and sometimes refer to it as the BDI-II, please double check that you language is consistent throughout the manuscript.

We describe the BDI-II in detail in the Methods section:

“BDI-II”
The Dutch translation of the BDI-II was used (van der Does, 2002). The BDI-II is a 21-item self-report questionnaire assessing depressive symptoms. BDI-II total scores < 14 reflect minimal level of depressive symptoms (Osman, 2008).

3. (Page 7, Line 43-51) Thank you for adding the section on the Mood Ratings. Given that you now have this section, it is thought that the description of the mood ratings provided in lines 26-41 of the same page would be better suited for this section.

We agree that details on the mood rating are more appropriate in the Mood Rating section, and have moved the examples of positive and negative mood ratings:

“To measure reactivity to the stress induction, participants rated their positive mood, negative mood, and their levels of calmness, anxiety, competence, and incompetence using Likert scales on which scores ranged from 1 (“not at all”) to 9 (“extremely”). In CBM studies, emotional reactivity is generally assessed by means of mood and anxiety ratings (Hallion & Ruscio, 2011). Questions about (in)competence were added because of the relevance to depression (Stanley & Maddux, 1986).

Mood ratings
We used the same positive mood (“How positive, happy or good do you feel right now?”) and negative mood (“How negative, sad or bad do you feel right now?”) items and Likert scales to measure participants’ mood before the pre-training bias assessment, after the training phase, after the four-minute distraction task and after the post-training bias assessment.‘

Because the ratings after the stress task reflect measurement of a different process (namely emotional reactivity in contrast to natural mood), we chose to discuss the scoring of the Likert scales within the section on the Stress task to ensure that the reader understands the scoring procedure. We hope you agree with this choice.

4. (Page 8, Line 48) You report that you’ve controlled for depression in all analyses, but then state the results of a series of ANOVAs rather than ANCOVAs. Please clarify.

Thank you for pointing this out. Indeed, we conducted ANCOVAs and not ANOVAs, and have corrected this throughout the manuscript.

5. (Page 9, Line 14) It is a bit confusing for the reader that Table 2 comes before Table 1. It may be helpful to switch this around.
Indeed. This has been adapted.

6. (Page 12, Line 38 -43) Thank you for adding this section examining study hypotheses among participants with a pre-training bias. The final sentences of this paragraph are somewhat confusing. Are you discussing within-subjects effects here? It would be helpful to provide a bit more interpretation of what these findings mean.

These were indeed within-subject effects of Time, presented separately for the negative and the positive training group. We included this information here and have also added a brief interpretation of these findings:

“There was a trend effect of Time within the negative training group, \( F(1,6) = 4.35, p = .08, f = .85 \), and a significant effect of Time in the positive training group, \( F(1,10) = 8.21, p < .05, f = .91 \). Training-congruent effects on incorrect recall were found when selecting participants with a pre-existing negative memory bias.”

7. (Page 13, Line 38-43) In your discussion you note that the positive training did not alter memory recall. Yet, in light of the pattern of findings now included within your results section on effects among participants with pre-training biases, this no longer seems true. Please revise this section to reflect on the new findings you have included within your results section.

We apologize for not discussing these new findings clearly. We have now revised the discussion of Study 2:

“In the total sample, the positive training might not have affected correct as well as incorrect recall because nondepressed healthy individuals generally tend to display positively biased processing (e.g., Tamir & Robinson, 2007). The finding that the positive training led to a more positive memory bias in a sub-sample of individuals with pre-existing negative memory bias suggests that negative memory biases can be altered. These results hold promise for memory bias training studies in clinically depressed samples.”

8. (Page 16, Line 16-17) In our initial review, we asked about power, since you had cited having a small sample size as a limitation of your studies. In your response you report that neither study was underpowered, but rather training effect may be smaller than anticipated.
As you have opted to keep a small sample as one of your limitations, we request that you clarify that this point.

We appreciate this point. Given that we expected a medium effect size of the training, both samples were large enough to yield training effects. Due to practical constrains, the community sample in Study 2 was smaller than the sample in Study 1. However, the community sample in Study 2 was more heterogeneous with respect to age, gender, educational level, and probably also with respect to biased memory (although our sample is too small to confirm this). Therefore, more differentiation and hence larger effects of the training were expected. Nevertheless, because mentioning this point in the discussion seems to raise questions and confusion, we now omit this limitation from the discussion section.

Reviewer #3: 

1. A figure/schematic overview of the procedure will improve comprehensibility.

Thank you for this suggestion. We have added a figure (Figure 1) to the Method section proving a schematic overview of the procedure.

2. A short description of the memory suppression manipulation of Joormann et al. (2009) (p. 4, line 9) could contribute to the reasoning about choosing for a new direct manipulation of memory recall.

Agreed, done: 

“Joormann, Hertel, LeMoult, and Gotlib (2009) manipulated mechanisms involved in memory suppression in depressed individuals. After learning to associate neutral cue words with either positive or negative targets, participants were instructed not to think about the negative targets when shown the neutral cues. There was an unaided condition, a positive-substitute condition and a negative-substitute condition. They found effects of the manipulation on emotional recall in both the positive and negative substitute conditions.”

3. Time between encoding and recall is relatively short. Of course time between both is too long to be considered as short term memory, and the distractor task minimizes short term memory effects, but nevertheless the time interval might be too short to cover the long term
episodic memory processes that are biased in depression. This could be mentioned in the discussion.

We agree that the time interval we used might have influenced our results. This point is now mentioned in the discussion:
“Moreover, time between encoding and recall might have been too short for stimuli to enter long-term episodic memory processes that are biased in depression. However, the time interval was too long for short-term memory, and the distraction task minimized any possible short-term memory effects.”

We hope that you and the reviewer will agree that the changes we made strengthens the manuscript, and that you will find the revised version acceptable for publication in the CBM special issue of Cognitive Therapy and Research.

Sincerely,
The authors.
Can memory bias be modified? The effects of an explicit cued-recall training in two independent samples.

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Cognitive models of emotional disorders posit that anxious and depressed individuals prioritize negative over positive and neutral information (Beck, 1976, 2008; Bower, 1981; Gotlib & Joormann, 2010). In addition, emotionally distressed individuals seem to lack the positive processing bias that characterizes healthy individuals (Bradley et al., 1997; Deldin, Keller, Gergen & Miller, 2001; Tamir & Robinson, 2007). Biased processing has most frequently been studied in three cognitive domains: attention, interpretation and memory. Negative biases in attention and interpretation have been well documented in anxiety and depression (e.g. Mathews & MacLeod, 2005; Peckham, McHugh & Otto, 2010). Generally, anxious individuals are vigilant for disorder-specific threat information, while depressed individuals elaborate more on negative information. Regarding interpretation, both anxious and depressed individuals tend to interpret ambiguous situations negatively (Mathews & MacLeod, 2005).

Moreover, over-general as well as negatively biased memory seems especially robust in depression (Matt, Vazquez & Campbell, 1992; Ridout, Noreen & Johal, 2009; Rinck & Becker, 2005; Williams, 1996; Williams et al., 2007). Depressed individuals tend to encode and recall negative information more easily than positive or neutral information. Biased memory in depression has been found most frequently using explicit memory tasks (Denny & Hunt, 1992; Ellwart, Rinck, & Becker, 2003; Watkins, Mathews, Williamson & Fuller, 1992). More specifically, neuroimaging studies indicate the encoding phase as especially important in biased memory processing (e.g. Arnold et al., 2011; Hamilton & Gotlib, 2008; van Wingen et al., 2010). Information-processing biases have been proposed to be related to the development and maintenance of emotional disorders (Clark & Steer, 1996). To test the causal relation between cognitive biases and emotional symptoms, studies using experimental manipulation of biases, Cognitive Bias Modification (CBM), have been conducted. In CBM, cognitive biases are directly
altered using computerized training procedures, and the consequences for clinically relevant symptoms are assessed (Mathews & MacLeod, 2002).

Studies applying CBM paradigms to healthy samples have shown that, in addition to manipulating biases, CBM also affects reactivity to subsequent stressors (Beard, Sawyer & Hofmann, 2012; MacLeod, Rutherford, Campbell, Ebeworthy & Holker, 2002; Mathews & Mackintosh, 2000; Wilson, MacLeod, Mathews & Rutherford, 2006). Individuals who have been trained to preferentially process negative information exhibit elevations of negative mood state in response to stress, relative to individuals who have been trained towards positive information. In addition to altering stress reactivity in healthy individuals, CBM has been found to be effective in the treatment of anxiety (see review and meta-analyses: Beard, Sawyer & Hofmann, 2012; Hakatama et al., 2010; Hallion & Ruscio, 2011). In contrast, investigators examining CBM have focused far less frequently on depression (Beard, Sawyer & Hofmann, 2012; Hertel & Mathews, 2011). Researchers have found positive-imagery training to affect interpretation bias and depressive symptoms in some depressed patients, but not in others (Blackwell & Holmes, 2010). Furthermore, whereas Wells and Beevers (2010) found attentional bias manipulation to lead to a reduction of depressive symptoms in dysphoric undergraduate students, Baert, De Raedt, Schacht and Koster (2010) found no general beneficial effect of attentional training in dysphoric students or depressed individuals. Thus, although CBM appears to affect emotional reactivity to stress in healthy individuals, the few studies conducted examining the effects of CBM in depression have yielded mixed results (Hallion & Ruscio, 2011). Given the prominent role of memory bias in depressed mood, CBM-memory paradigms might provide stronger effects.

In contrast to interpretation and attention, manipulation of memory biases has received relatively little attention (Hertel & Mathews, 2011). Some studies have successfully manipulated interpretation bias in healthy individuals and have found a subsequent effect on recall of
Memory Bias Modification

emotional stimuli, although they do not provide evidence of changes in mood as a consequence of the training (Hertel, Vasques, Benbow & Hughes, 2011; Salemink, Hertel & Mackintosh, 2010; Tran, Hertel & Joormann, 2011). Joormann, Hertel, LeMoult and Gotlib (2009) manipulated mechanisms involved in memory suppression in depressed individuals. After learning to associate neutral cue words with either positive or negative targets, participants were instructed not to think about the negative targets when shown the neutral cues. There was an unaided condition, a positive-substitute condition and a negative-substitute condition. They found effects of the manipulation on emotional recall in both the positive and negative substitute conditions. Taken together, these studies suggest that memory biases can be manipulated; it is not known, however, whether memory biases can be manipulated directly by training emotional recall. Moreover, although investigators have yet to demonstrate that CBM of memory can affect mood, direct manipulation of emotional recall might instigate stronger effects, especially given that memory of emotional events has been found to exert a clear effect on mood and well-being (e.g. Charles, Mather & Carstensen, 2003; Joormann & Siemer, 2004). In the present paper, explicit verbal episodic long-term memory of emotional verbal stimuli was manipulated in two experiments through a cued-recall training of either positive or negative words. A student sample was tested in the first study and a sample from the general population in the second study. Participants were expected to adapt a strategy during training to preferentially encode training-congruent valenced stimuli (e.g. van Wingen et al., 2010), resulting in stronger training-congruent biased recall after the training than before. In order to examine how the training affected memory bias, we distinguished between specific and global memory bias. Here, specific memory is related to correct recall of learned stimuli, whereas global memory refers to (incorrect) recall of non-learned verbal emotional information. The effect of the training on mood and emotional reactivity to stress was also assessed. Participants in the negative training condition
Memory Bias Modification

were expected to display more negative emotional reactivity after a stressor. If direct manipulation of emotional recall alters emotional memory in healthy individuals and affects mood and emotional reactivity to stress, emotional recall training might offer relief for depressed individuals.

Study 1

Method

Participants

A total of 80 undergraduate students from Radboud University Nijmegen, The Netherlands, participated in this study. Participants were randomly assigned to the negative memory training (NMT) or positive memory training (PMT) conditions. The two groups did not differ on age (M = 19.7, SD = 1.9 for NMT; M = 19.7, SD = 2.4 for PMT), F(1,78) = .01, p = .96, f = .01 or sex (85% female NMT, 75% female PMT), F(1,78) = 1.24, p = .27, f = .13. There was, however, a significant group difference on total Beck Depression Inventory score (BDI-II; Beck, Steer & Brown, 1996; M = 4.2, SD = 4.6 for NMT; M = 6.8 SD = 6.4 for PMT, F(1,78) = 4.65, p = <.05, f = .24); the group difference was small, however, and the means were low in both groups. All participants spoke fluent Dutch and received course credit for their participation.

Materials, Apparatus and Procedure

BDI-II

The Dutch translation of the BDI-II was used (van der Does, 2002). The BDI-II is a 21-item self-report questionnaire assessing depressive symptoms. BDI-II total scores < 14 reflect minimal level of depressive symptoms (Osman, 2008).

Memory bias assessments
Memory Bias Modification

To assess memory bias, we presented participants with 20 Dutch words (10 positive; 10 negative), one at a time, for 10 seconds each. All words were presented on a computer screen in white on a black background. Participants were instructed to memorize the words for subsequent recall. Explicit memory instructions were given to make sure that the learning processes in the pre- and the post-training bias assessments were similar: because the experiment consisted of a series of memory tasks, participants would quickly learn that they are asked to recall the presented words after a distraction. Therefore, no more than two words of the same valence were presented consecutively, and all words were selected on valence and matched for length and frequency in the Dutch language (from Dutch translation of Affective Norms for English Words database; ANEW; Bradley & Lang, 1999). After a two-minute distraction task (Raven matrices; Raven, 1958), participants were instructed to write down as many of the words they could remember. Memory bias was assessed by examining whether participants wrote down more negative or more positive words. Here we examined both correct and incorrect recall.

We examined memory bias before and after training. We counterbalanced the order of word sets that were used before and after training. To stimulate recall and avoid floor effects, the post-training assessment differed from the pre-training assessment in that participants were told that they would receive monetary incentive for correctly recalled words.

Memory bias training

The memory bias training consisted of six cued-recall memory tasks, presented in a random order for each participant. Similar to the bias assessments, participants had to memorize 10 positive and 10 negative words. After a one-minute distraction task (Raven matrices), participants were presented with training-congruent fragments of the previously encoded words. To train a bias towards recall of negative words, we presented half of the participants with negative word fragments (negative training). To train a bias to recall positive words, we
presented the other half of the participants with positive word fragments (positive training). To keep the participants from becoming aware of the purpose of the training, some training-incongruent fragments were included in the recall phase of the memory tasks. Out of the six cued-recall memory tasks, two tasks included one training-incongruent fragment, two tasks two training-incongruent fragments, one task three training-incongruent fragments and one task none. In order to stimulate correct recall, the first letter of the word was always presented and only a few letters were missing. Participants were instructed to use a computer keyboard to type the correct word. The emotionality of the stimuli in the training might have influenced participants’ mood state. We aimed at measuring the effect of the training on recall bias and not the effect of mood per se, therefore a four-minute distraction task (Raven matrices) preceded the post-training bias assessment in order to reduce any possible mood effects of the training.

**Stress task**

Participants were instructed to solve 20 anagrams (presented one at a time in white on a black background) as quickly and accurately as possible and to write the answers on a sheet of paper. Participants were instructed that verbal intelligence was assessed and that they should be able to solve most anagrams, although in fact, the anagrams were difficult or unsolvable. To increase stress, participant were given only 20 seconds to solve each anagram; we also presented a count-down clock in the top right corner of the computer screen in red. A loud buzzer sounded when the time was up and the next anagram appeared automatically. To measure reactivity to the stress induction, participants rated their positive mood, negative mood, and their levels of calmness, anxiety, competence and incompetence using Likert scales on which scores ranged from 1 (“not at all”) to 9 (“extremely”). In CBM studies, emotional reactivity is generally assessed by means of mood and anxiety ratings (Hallion & Ruscio, 2011). Questions about (in)competence were added because of the relevance to depression (Stanley & Maddux, 1986).
Memory Bias Modification

Mood ratings

We used the same positive mood ("How positive, happy or good do you feel right now?") and negative mood ("How negative, sad or bad do you feel right now?") items and Likert scales to measure participants’ mood before the pre-training bias assessment, after the training phase, after the four-minute distraction task and after the post-training bias assessment.

Procedure

A schematic overview of the procedure is presented in Figure 1. Participants first completed an informed consent form, demographic questions and the BDI-II. Next, participants completed the pre-training bias assessment, the bias training and the post-training bias assessment. Participants then completed the stress task. A four-minute clip of a cheerful movie (‘Happy feet’) was shown to erase possible negative mood of the training. Participants were then debriefed and rewarded for the correctly recalled words during the post-bias assessment before they left the session. Participants received one Euro for every three words that they recalled correctly. The training phase lasted for approximately 40 minutes and the whole study lasted for about 1.5 hours.

Results

Memory bias

A difference-score representing recall bias was calculated by subtracting the number of correctly recalled negative words from the number of correctly recalled positive words. We also calculated a recall-bias score for incorrectly recalled words, pre- as well as post-training. An independent rater, blind to the participant’s training condition, rated the valence of all incorrect answers. Only distinctly positive and negative answers were included (the few neutral and valence-unspecific answers were disregarded). When in doubt about the valence, the rater noted
Memory Bias Modification

the word down including his/her rating and the experimenter gave a second opinion. BDI-II total score was included as a covariate in all following analyses to control for the baseline difference between NMT and PMT participants. The groups did not differ at baseline on correct recall bias, $F(1,77) = .16, p = .69, f = .04$, or incorrect recall bias, $F(1,77) = .11, p = .74, f = .03$. A Training (positive, negative) x Time (pre, post) repeated-measures analysis of variance (ANCOVA) on difference scores for correctly and incorrectly recalled words during the bias assessments did not yield a significant interaction, $F(1,77) = 1.23, p = .27, f = .13$. We also report the Training x Time interaction for correctly and incorrectly recalled words separately, because we did not only wanted to compare the effect of the training between correct recall and incorrect recall, but also examine the effect of the training per memory bias measure. A Training (positive, negative) x Time (pre, post) repeated-measures ANCOVA conducted on difference score for correctly recalled words during the bias assessments did not yield a significant interaction, $F(1,77) = 1.10, p = .30, f = .12$. An ANCOVA conducted on difference score for incorrect recall did not yield a significant two-way interaction either, $F(1,77) = .44, p = .51, f = .08$. Taken together, this suggests that the training did not differentially affect memory retrieval of valenced verbal information (see Table 1 for mean recall rates, mean recall-bias scores and standard deviations). The effect of the training remained nonsignificant when selecting participants with a pre-existing negative memory bias (19 NMPs and 17 PMTs with pre-training correct-recall difference score $<0$, indicating more negative relative to positive recall), $F(1,33) = 1.74, p = .20, f = .23$ for Training x Time on correct recall and $F(1,33) = .36, p = .55, f = .11$ on incorrect recall. The effect of the training remained nonsignificant when selecting participants with a pre-existing negative memory bias (19 NMPs and 17 PMTs with pre-training correct-recall difference score $<0$, indicating more negative than positive recall), $F(1,33) = 1.74, p = .20, f = .23$, for Training x Time on correct recall, and $F(1,33) = .36, p = .55, f = .11$, on incorrect recall.
Memory Bias Modification

Emotional reactivity

Training type also did not affect emotional reactivity to the stress task, measured by positive mood, negative mood, calmness, anxiety, competence and incompetence (see Table 2; all p-values > .10).

Mood throughout experiment

Mood state throughout the experiment was assessed for positive mood and negative mood separately. The Training (positive, negative) x Time (baseline, after training, after distraction, after post bias assessment) interaction was nonsignificant, $F(3,75) = .48, p = .70, f = .14$, for positive mood ratings. Neither was the Training x Time interaction with negative mood ratings as dependent variable, $F(3,75) = 1.43, p = .24, f = .24$. See Table 2 for means and standard deviations.

Discussion

In this study we applied a novel CBM paradigm in a first attempt to modify explicit memory bias through cued emotional recall training. Contrary to predictions, we did not find evidence of an effect of the training on explicit verbal episodic memory bias (either specific recall of trained stimuli or more global retrieval from memory), on reactivity to a stress task, or on mood throughout the experiment. The results indicate that these specific emotional memory processes may not be easily modified in healthy individuals, nor in individuals with a pre-existing negative memory bias. Undergraduate students are, however, a highly selective and homogeneous group; they are generally young, highly educated, and often have a high socioeconomic status. Therefore, we tested our hypotheses with a community sample in the United States. We used the same paradigm, with one adaptation to the post-memory bias assessment. In Study 1, participants were unaware before encoding that the recall phase of the
post-training bias assessment differed from the training. To stimulate recall, in Study 2 the participants were made aware before encoding that they would not be presented with word fragments during the recall phase, but instead would be asked to freely recall the encoded words.

Study 2

Method

Participants

A total of 52 individuals from the community in the Stanford area (CA, USA) participated in this study. Allocation to the conditions was similar to Study 1, resulting in a negative (NMT) and positive memory training group (PMT). The two groups did not differ significantly with respect to age (M = 39.2 SD = 13.7 for NMT, M = 34.8 SD = 12.5 for PMT), $F(1,50) = 1.50, p = .23, f = .17$, sex (52% female NMT, 58% female PMT), $F(1,50) = .17, p = .68, f = .05$, or BDI-II total scores (M = 3.8 SD = 4.7 for NMT, M = 5.4 SD = 8.1 for PMT), $F(1,50) = .74, p = .39, f = .12$. One-quarter (25.0%) of the participants had a college degree. All participants spoke fluent English and received payment for their participation.

Materials and Apparatus

Memory bias assessments

The procedure was the same as in Study 1. There were only two differences in the assessment phase: English words were selected from the ANEW database (Bradley & Lang, 1999) and in the post-training bias assessment, participants were informed of the upcoming free recall before encoding began (in contrast to the cued recall during the training phase).

Memory bias training, stress task and mood ratings
Memory Bias Modification

The memory bias training phase and the stress task were identical to Study 1, except that English words were selected. Due to a programming error, there was no mood rating after the four-minute distraction.

Results

Memory bias

The groups did not differ at baseline on correct recall bias, $F(1,50) = .12, p = .73, f = .04$, or incorrect recall bias, $F(1,50) = .18, p = .68, f = .05$. A Training (positive, negative) x Time (pre, post) repeated-measures ANOVA on difference scores for correctly and incorrectly recalled words during the bias assessments yielded a significant interaction, $F(1,50) = 11.06, p < .005, f = .47$. A Training (positive, negative) x Time (pre, post) repeated-measures ANOVA conducted on the recall bias for correctly recalled words did not yield a significant interaction, $F(1,50) = 2.70, p = .11, f = .23$. We did, however, find a significant main effect of Condition, $F(1,50) = 4.35, p < .05, f = .29$; in that, participants in the negative training condition correctly recalled on average more positive than negative words compared to participants in the positive memory training condition, when collapsing across Time. A Training (positive, negative) x Time (pre, post) repeated measures ANOVA conducted on the incorrect recall bias yielded a significant two-way interaction, $F(1,50) = 8.51, p < .01, f = .41$. Follow-up analyses revealed that the participants in the negative training condition exhibited a greater tendency to incorrectly retrieve negative relative to positive words from memory than did participants in the positive training condition after the training, $F(1,50) = 8.95, p < .005, f = .42$, but not before. Incorrect recall bias scores did not correlate significantly with any of the mood ratings, BDI-II total score, age, or sex (correlation coefficients between -.14 and .24 and $p$-values between .08 (for sex and incorrect recall post-training) and .95; see Table 1 for means and standard deviations).
When selecting participants with a pre-training negative memory bias (7 NMPs and 11 PMTs with pre-training correct-recall difference score < 0), the Training (positive, negative) x Time (pre, post) interaction on difference scores for correctly and incorrectly recalled words remained significant, $F(1,16) = 17.24, p < .005, f = 1.04$. Furthermore, the Training x Time interaction was nonsignificant for correct recall, $F(1,16) = 2.96, p = .10, f = .43$, and significant for incorrect recall bias, $F(1,16) = 12.10, p < .005, f = .87$. The groups did not differ pre-training ($M = 0.0 SD = 1.0$ for NMT, $M = 0.0 SD = 1.8$ for PMT), $F(1,16) = 0.00, p = 1.00, f = .00$. Post-training, NMTs ($M = -2.9 SD = 3.6$) incorrectly recalled more negative relative to positive words, in comparison to PMTs ($M = 2.5 SD = 2.2$), $F(1,16) = 15.63, p < .005, f = .99$. There was a trend effect of Time within the negative training group, $F(1,6) = 4.35, p = .08, f = .85$, and a significant effect of Time in the positive training group, $F(1,10) = 8.21, p < .05, f = .91$. Training-congruent effects on incorrect recall were found when selecting participants with a pre-existing negative memory bias.

**Emotional reactivity**

Emotional reactivity and mood ratings were missing for two participants. Training type did not affect emotional reactivity to the stress task (see Table 2; all p-values $\geq .30$).

**Mood throughout experiment**

A nonsignificant interaction of Training (positive, negative) and Time (baseline, after training, after post-training bias assessment) for negative mood ratings was observed, $F(2,47) = 2.21, p = .12, f = .31$. The interaction of Training (positive, negative) and Time (baseline, after training, after post-training bias assessment) for positive mood ratings was not significant either, $F(2,47) = .10, p = .91, f = .06$. See Table 2 for means and standard deviations.

**Discussion**
The results of Study 2 largely replicated the results of Study 1, in that explicit memory bias for trained emotional verbal stimuli was not differentially affected by the cued recall training. In addition, no effect on emotional reactivity after the stress task or on mood throughout the experiment was found. A training-congruent incorrect recall pattern of valenced words was found at the post-training bias assessment, indicating that the negative training affected global memory bias towards negative information. Thus, in a community sample, directly training recall of emotional words did not affect recall of the trained stimuli on a subsequent task, but stimulated a more global retrieval effect as negative words became more accessible after the negative training. This pattern of results was also found in a sub-sample of individuals with pre-existing negative memory bias. Here, the positive training induced a positive explicit memory bias.

In the total sample, the positive training might not have affected correct as well as incorrect recall because nondepressed healthy individuals generally tend to display positively biased processing (e.g., Tamir & Robinson, 2007). The finding that the positive training led to a more positive memory bias in a sub-sample of individuals with pre-existing negative memory bias suggests that negative memory biases can be altered. These results hold promise for memory bias training studies in clinically depressed samples.

General Discussion

Studies 1 and 2 were designed to assess whether explicit emotional memory bias can be modified in healthy individuals by means of a computerized cued-recall training and whether mood and emotional reactivity to stress are affected by such a memory bias training. This study provides first tentative insights into the malleability of memory bias. We found no indication of a differential effect of the training on explicit verbal memory bias for trained stimuli or emotional reactivity to stress. These first results offer little support for the effectiveness of directly
modifying emotional recall on explicit memory bias and on emotional reactivity to a stressor (consistent with Hertel et al., 2011). The effect on incorrect recall in the community sample in Study 2 indicates that the training might increase the accessibility of training-congruent emotional information in long term memory. A general increase in accessibility of negative information in the negative training condition could increase the likelihood that an individual will mistake an incorrect negative word for a relevant word, whereas it would not improve their ability to distinguish correct negative words from irrelevant negative words during retrieval.

Based on the results, this tendency may be stronger in individuals with a pre-existing negative memory bias, as they may be more sensitive to the training. Although previous CBM studies targeting interpretation and attention in depression have not yielded promising results, the effect on emotional incorrect recall in Study 2 suggests that it would be productive to examine the effect of CBM-memory paradigms in clinical samples, particularly because memory bias is regarded as characteristic of depression (e.g., Matt et al., 1992). Although biased memory processing might not be malleable by directly targeting recall of emotional events, trying to make the emotionality of long term memories less negative might have beneficial effects on more general involuntary emotional thought patterns. Certainly, this formulation is speculative and requires empirical substantiation.

The primary difference between the paradigms in the two studies was the instruction at the start of the post-training bias assessment. Participants in Study 2 were told before encoding that, in contrast to the training phase, a free recall would follow after the brief distraction. This might have led participants to exert more effort during encoding, which in turn resulted in a congruent effect of the training on incorrect recall bias. This explanation is supported by the overall higher incorrect recall rates in Study 2 than in Study 1. The difference in the effect on incorrect recall between Study 1 and 2 might also be due to the student sample generally having
stronger executive control. The undergraduates in Study 1 were younger than the community participants in Study 2 and had a higher level of education and, therefore, may have had a cognitive advantage that led them to be more resistant to a direct memory bias training. If substantiated, this would mean that the memory bias modification might be more successful in clinically depressed individuals, who generally suffer from executive dysfunction (Harvey et al., 2004). Taken together with the previous studies on memory bias modification (Hertel & Mathews, 2011), it seems that in contrast to cognitive domains like attention and interpretation, memory bias is more easily affected through modifying processing in another domain than directly through recall. This is consistent with the Combined Cognitive Bias hypothesis, which holds that attention to and interpretation of emotional stimuli lead to processing biases in memory (Everaert, Koster & Derakshan, 2012).

These findings represent a preliminary step in research on memory bias modification, given there are several limitations of these studies. We hypothesize that participants would adapt a training-congruent encoding strategy due to the valence-specific cued-recall training. However, the results do not cater to the questions whether encoding or retrieval processes were affected by the training. This paradigm targeted a highly specific domain, namely explicit episodic memory bias for positive and negative verbal stimuli. Adaptations to the paradigm - e.g. more implicit training and assessment of bias - may provide more compelling results. Moreover, time between encoding and recall might have been too short for stimuli to enter long-term episodic memory processes that are biased in depression. However, the time interval was too long for short-term memory, and the distraction task minimized any possible short-term memory effects. Not using self-referential stimuli or self-referent encoding instructions might have contributed to the failure to find an effect of the training on biased memory of trained stimuli. Although according to Beck’s schema theory (1976; 2008; and see Banôs, Medina & Pascual, 2001), relatedness to the
self-concept is especially relevant in depression, it might have hampered the effectiveness of our memory training in healthy individuals. Also, incidental learning generally offers stronger results than intentional learning (Mathews & MacLeod, 1994). Having to provide explicit memory instructions might have weakened the training effects. Furthermore, the effect of the training might also be weakened by including fragments of training-incongruent valenced words. What is more, exhaustion might have contributed to lower recall rates post-training compared to pre-training, which may have obscured the training effects. Although our results do not provide information on the general stability of memory bias, memory processes are regarded to be rather stable and robust and might not be easily affected by a brief single-session CBM paradigm, especially in healthy non-vulnerable individuals (Hallion & Ruscio, 2011). In this context, it would be interesting to examine the effects of multiple-session CBM memory training with self-referential stimuli. In future studies, adding a neutral training-condition will help with interpretation of the results. Applying such a memory bias modification paradigm to a vulnerable or clinically depressed sample would provide insight into the malleability of their negative memory biases.


Memory Bias Modification


Memory Bias Modification


Table 1

Mean scores, standard deviations (SD) and statistics of group comparison for positive and negative mood ratings throughout the study as well as calmness, anxiety, competence and incompetence ratings after the stress task per sample (NMT and PMT in Study 1 and Study 2). In Study 1, BDI-II total score was included as covariate.

<table>
<thead>
<tr>
<th></th>
<th>NMT</th>
<th>PMT</th>
<th>Stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pos. baseline</td>
<td>7.3 (1.0)</td>
<td>7.2 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Pos. after training</td>
<td>6.7 (1.1)</td>
<td>6.6 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Pos. after distraction</td>
<td>6.7 (1.3)</td>
<td>6.7 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Pos. after post assessment</td>
<td>6.5 (1.3)</td>
<td>6.6 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Neg. baseline</td>
<td>1.7 (1.3)</td>
<td>2.0 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Neg. after training</td>
<td>2.2 (1.2)</td>
<td>2.2 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Neg. after distraction</td>
<td>2.0 (1.2)</td>
<td>1.9 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Neg. after post assessment</td>
<td>2.3 (1.4)</td>
<td>2.1 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Pos. after stress</td>
<td>5.7 (1.6)</td>
<td>5.9 (1.7)</td>
<td>$F(1,77) = 1.94, p = .17, f^2 = .16$</td>
</tr>
<tr>
<td>Neg. after stress</td>
<td>2.8 (1.6)</td>
<td>2.6 (1.6)</td>
<td>$F(1,77) = 1.68, p = .28, f^2 = .15$</td>
</tr>
<tr>
<td>Calmness after stress</td>
<td>6.4 (1.7)</td>
<td>6.4 (1.6)</td>
<td>$F(1,77) = .27, p = .61, f^2 = .05$</td>
</tr>
<tr>
<td>Anxiety after stress</td>
<td>2.1 (1.4)</td>
<td>2.2 (1.3)</td>
<td>$F(1,77) = .02, p = .89, f^2 = .00$</td>
</tr>
<tr>
<td>Competence after stress</td>
<td>5.0 (1.8)</td>
<td>5.3 (2.0)</td>
<td>$F(1,77) = 1.53, p = .22, f^2 = .14$</td>
</tr>
<tr>
<td>Incompetence after stress</td>
<td>3.5 (1.8)</td>
<td>4.1 (2.0)</td>
<td>$F(1,77) = .31, p = .58, f^2 = .06$</td>
</tr>
</tbody>
</table>
Table 1 continued

<table>
<thead>
<tr>
<th></th>
<th>NMT Mean (SD)</th>
<th>PMT Mean (SD)</th>
<th>Stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pos. baseline</td>
<td>7.2 (1.0)</td>
<td>6.4 (1.7)</td>
<td>-</td>
</tr>
<tr>
<td>Pos. after training</td>
<td>6.5 (1.3)</td>
<td>5.8 (1.7)</td>
<td>-</td>
</tr>
<tr>
<td>Pos. after post assessment</td>
<td>6.1 (1.7)</td>
<td>5.5 (1.9)</td>
<td>-</td>
</tr>
<tr>
<td>Neg. baseline</td>
<td>1.6 (1.7)</td>
<td>2.6 (2.0)</td>
<td>-</td>
</tr>
<tr>
<td>Neg. after training</td>
<td>2.2 (1.6)</td>
<td>2.6 (1.9)</td>
<td>-</td>
</tr>
<tr>
<td>Neg. after post assessment</td>
<td>2.4 (1.6)</td>
<td>3.0 (2.3)</td>
<td>-</td>
</tr>
<tr>
<td>Pos. after stress</td>
<td>5.0 (2.1)</td>
<td>4.7 (2.2)</td>
<td>$F(1,48) = .21, p = .65, f^2 = .06$</td>
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<tr>
<td>Neg. after stress</td>
<td>3.3 (2.1)</td>
<td>3.8 (2.8)</td>
<td>$F(1,48) = .46, p = .50, f^2 = .10$</td>
</tr>
<tr>
<td>Calmness after stress</td>
<td>5.0 (2.0)</td>
<td>5.2 (2.0)</td>
<td>$F(1,48) = .25, p = .62, f^2 = .07$</td>
</tr>
<tr>
<td>Anxiety after stress</td>
<td>3.5 (2.0)</td>
<td>4.1 (2.1)</td>
<td>$F(1,48) = 1.08, p = .30, f^2 = .15$</td>
</tr>
<tr>
<td>Competence after stress</td>
<td>4.8 (2.2)</td>
<td>4.7 (2.4)</td>
<td>$F(1,48) = .02, p = .90, f^2 = .00$</td>
</tr>
<tr>
<td>Incompetence after stress</td>
<td>3.8 (2.3)</td>
<td>4.3 (2.4)</td>
<td>$F(1,48) = .44, p = .61, f^2 = .10$</td>
</tr>
</tbody>
</table>
Table 2

*Mean scores and standard deviations (SD) for correct and incorrect recall rates as well as difference scores (# positive minus # negative words, in bold) on the pre-training and post-training bias assessments per sample (NMT and PMT in Study 1 and Study 2).*

<table>
<thead>
<tr>
<th>Study 1</th>
<th>NMT</th>
<th>PMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Pre pos. correct recall</td>
<td>4.25 (1.67)</td>
<td>4.08 (1.82)</td>
</tr>
<tr>
<td>Pre neg. correct recall</td>
<td>4.58 (2.07)</td>
<td>4.45 (1.48)</td>
</tr>
<tr>
<td>Pre pos.-neg. correct recall</td>
<td><strong>-.33 (2.42)</strong></td>
<td><strong>-.38 (1.66)</strong></td>
</tr>
<tr>
<td>Post pos. correct recall</td>
<td>2.80 (1.64)</td>
<td>2.60 (1.60)</td>
</tr>
<tr>
<td>Post neg. correct recall</td>
<td>2.88 (1.51)</td>
<td>3.17 (1.57)</td>
</tr>
<tr>
<td>Post pos.-neg. correct recall</td>
<td><strong>-.08 (2.08)</strong></td>
<td><strong>-.58 (1.65)</strong></td>
</tr>
<tr>
<td>Pre pos. incorrect recall</td>
<td>.40 (.59)</td>
<td>.40 (.59)</td>
</tr>
<tr>
<td>Pre neg. incorrect recall</td>
<td>.50 (.68)</td>
<td>.60 (.98)</td>
</tr>
<tr>
<td>Pre pos.-neg. incorrect recall</td>
<td><strong>-.10 (.87)</strong></td>
<td><strong>-.20 (.99)</strong></td>
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<tr>
<td>Post pos. incorrect recall</td>
<td>.98 (1.00)</td>
<td>1.03 (1.03)</td>
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<tr>
<td>Post neg. incorrect recall</td>
<td>.93 (1.10)</td>
<td>.85 (1.35)</td>
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<td>Post pos.-neg. incorrect recall</td>
<td><strong>.05 (1.38)</strong></td>
<td><strong>.18 (1.50)</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study 2</th>
<th>NMT</th>
<th>PMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Pre pos. correct recall</td>
<td>3.31 (1.76)</td>
<td>3.38 (1.79)</td>
</tr>
<tr>
<td></td>
<td>Pre neg. correct recall</td>
<td>Post pos. correct recall</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td>2.92 (1.90)</td>
<td>3.12 (1.66)</td>
</tr>
<tr>
<td>Pre pos.-neg. correct recall</td>
<td><strong>.38 (2.19)</strong></td>
<td><strong>.77 (1.95)</strong></td>
</tr>
<tr>
<td></td>
<td>1.31 (1.54)</td>
<td>1.65 (2.30)</td>
</tr>
<tr>
<td>Pre pos.-neg. incorrect recall</td>
<td><strong>.19 (1.77)</strong></td>
<td><strong>-.58 (1.33)</strong></td>
</tr>
<tr>
<td></td>
<td>1.19 (1.50)</td>
<td>1.42 (1.36)</td>
</tr>
<tr>
<td>Post pos.-neg. incorrect recall</td>
<td><strong>.04 (1.43)</strong></td>
<td><strong>1.50 (2.04)</strong></td>
</tr>
</tbody>
</table>


Figure 1

Schematic overview of procedure. Positive and negative mood assessments are marked with an asterisk *

- consent form and questionnaires
  - pre-training bias assessment
    - positive bias training
    - negative bias training
      - distraction
        - post-training bias assessment
          - stress task
            - cheerful movie
              - debriefing and payment
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