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Cognitive Bias Modification: Induced Interpretive Biases Affect Memory

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Previous research has shown that it is possible to experimentally induce interpretive biases using ambiguous scenarios. This study extends past findings by examining the effects of cognitive bias modification for interpretation on subsequent scenario recall. Participants were trained to interpret emotionally ambiguous passages in either a positive or negative direction. Transfer of the training to novel scenarios was tested. After training, participants were also asked to recall details from these novel scenarios. The results indicate that the training was effective in inducing the intended group differences in interpretive bias. Importantly, participants exhibited memory biases that corresponded to their training condition. These results suggest that manipulating interpretive biases can result in corresponding changes in memory. Findings from this study highlight the importance of future research on the relation among cognitive biases and on the possibility of modifying cognitive biases in emotional disorders.

Keywords: cognitive bias modification, training, interpretation, memory

Cognition plays a critical role in human emotion. According to cognitive theories of emotion, appraisals or interpretations of the situation determine if an emotion is experienced and which emotion is experienced (Ellsworth & Scherer, 2003; Siemer, Mauss, & Gross, 2007). Cognition, therefore, is also the primary route through which emotions can be regulated. Cognitive reappraisal or the reinterpretation of the emotion-eliciting situation, for example, is a particularly effective emotion regulation strategy (Gross & John, 2002). In addition, studies have shown that memory plays a critical role in the regulation of negative affect. Investigators studying the relation between mood and memory have proposed that mood-incongruent recall can be a powerful mood and emotion regulation strategy (Erber & Erber, 1994; Parrott & Sabini, 1990; Rusting & DeHart, 2000) and that people actively retrieve pleasant thoughts and memories in an attempt to regulate or reverse unpleasant moods (e.g., Josephson, Singer, & Salovey, 1996). Not surprisingly, individual differences in mood-congruent memory and in the accessibility of mood-incongruent material have been proposed to predict the ability to regulate negative mood states (Joormann & Siemer, 2004; Joormann, Siemer, & Gotlib, 2007). In addition, the tendency to recall positive events and forget negative events is associated with higher levels of well-being over the course of one's life (Charles, Mather, & Carstensen, 2003).

Consequently, cognitive biases in the initial processing of events as well as in the memory for these events may affect emotion experience and interfere with one's ability to regulate affect, thereby setting the stage for an increased vulnerability to emotional disorders (Joormann, Yoon, & Siemer, 2009). Indeed, cognitive theories of emotional disorders posit that depressed and anxious individuals and people who are at risk for developing these disorders exhibit cognitive biases in various aspects of information processing, including interpretation and memory (Mathews & MacLeod, 2005). These theories further propose that cognitive biases are not just an epiphenomenon of these disorders, but instead play an important role in increasing the risk for the onset, maintenance, and recurrence of disorders. Recent reviews suggest, for example, that depressed people demonstrate increased elaboration of negative material and a tendency to interpret ambiguous material in a mood-congruent manner (e.g., Mathews & MacLeod, 2005). In addition, biased memory for negative, relative to positive, information represents perhaps the most robust cognitive finding associated with major depression. In a meta-analysis of studies assessing recall performance, Matt, Vasquez, and Campbell (1992) found that people with major depression remember 10% more negative words than positive words. Nondepressed controls, in contrast, demonstrated a positive memory bias, in that they recalled 8% more positive than negative words.

Given the importance of cognition for everyday emotion regulation and risk for emotional disorders, modifying cognitive biases may change people's reactivity to emotion-eliciting events and may improve their ability to regulate negative affect. Furthermore, research on how to alter these biases may provide important insight into processes that underlie the onset and maintenance of disorders and thus holds great promise for treatment and prevention efforts. Indeed, recent research has investigated the impact of bias modification on various outcome measures including depression and anxiety symptoms, as well as responses to acute stressors. Some of these studies have focused on manipulating attention by guiding participants to attend to either threatening or emotionally

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neutral stimuli (or to avoid threatening stimuli). Results show that after attention training away from threat, participants reported reduced negative affect to a standardized stress manipulation (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002) or upon arrival at college abroad (See, MacLeod, & Bridle, 2009). After the training of positive attentional biases, participants looked less at negative images during a stress induction (Wadlinger & Isaacowitz, 2008). As outlined previously, however, interpretation and memory biases have particularly detrimental effects on the ability to regulate negative mood states and may increase risk for the onset and maintenance of debilitating emotional disorders. Using emotionally ambiguous homographs, Gray and Mathews (2000) demonstrated that interpretive biases can be induced, and that participants are often not aware of this modification. In a related study, Mathews and Mackintosh (2000) used ambiguous scenarios to train individuals to make either nonanxious or anxious interpretations of subsequent ambiguous situations. In addition, participants who were trained to interpret ambiguity in a nonthreatening manner had an attenuated anxiety reaction to a subsequent video stressor (Wilson, MacLeod, Mathews, & Rutherford, 2006; see also Mackintosh, Mathews, Yiend, Ridgeway, & Cook, 2006). Finally, training positive biases using imagery helped to alleviate a subsequently induced negative mood state in a nonclinical sample (Holmes, Lang, & Shah, 2009). Importantly, effects of interpretive training on anxiety have been shown to remain stable after a 24-hr delay between training and test (Yiend, Mackintosh, & Mathews, 2005).

Modifying interpretation biases may not only hold great promise because it affects the interpretation of novel scenarios and responses to stressors, but changes in interpretation may also affect memory. Hirsch, Clark, and Mathews (2006) recently pointed out that cognitive biases do not operate in isolation but rather influence and interact with one another. Moreover, evidence from reconstructive memory research indicates that the way in which events are interpreted determines how they are remembered (Bartlett, 1932). If individuals tend to interpret situations in a negative manner, they may also be more likely to remember them in a way that reflects this initial interpretation. Memory biases may therefore be linked to initial biases in interpretation (Hertel, 2004), although very few studies have empirically investigated this possibility. Among the few is a recent study by Hertel, Brozovich, Joormann, and Gotlib (2008) who examined the connection between interpretation and memory in individuals diagnosed with social phobia. When asked to recall details from previously presented ambiguous scenarios, socially anxious compared to nonanxious participants tended to produce more distortions that reflected their initial negative interpretations of the scenarios. This result suggests that memory biases can be produced by biased interpretations and that modifying the initial interpretation of events could prevent subsequent biases in memory.

The present study was designed to investigate whether interpretation-bias training not only affects the interpretation of novel scenarios, but also participants' reconstructive memory for these scenarios. Modifying memory may, in turn, affect mood, emotional vulnerability, and future interpretations crucial to the development and maintenance of emotional disorders. Evidence for the causal role of interpretation bias in memory distortion could also provide possible directions for clinical interventions. To investigate the effect of cognitive bias modification of interpretation (CBM-I), we randomly assigned participants to a positive or negative interpretation training group using ambiguous social scenarios and assessed the transfer of this training on the subsequent interpretation of novel ambiguous scenarios. The intention of the training was not to target depression- or anxiety-specific emotions, but instead to train participants to interpret material in a generally positive or negative light. Specifically, we predicted that participants' response latencies to training-congruent and -incongruent interpretations of ambiguous scenarios should reflect their training condition. Thus, as training progresses participants in the positive compared to the negative training group should be faster to respond to sentences that describe positive interpretations. In addition, we predicted that training would transfer to the novel scenarios presented after training completion and would affect whether positive or negative interpretations of these scenarios will be judged as being more or less similar to the novel scenarios. Thus, participants in the positive compared to the negative training group, should judge positive interpretations as more similar to the ambiguous scenarios. Importantly, to investigate the relation between interpretation and memory biases, we also asked participants to recall these novel scenarios, guided by the hypothesis that interpretation training not only changes participants' interpretations of novel scenarios, but also induces a matching memory bias. We predicted that the interpretation training leads to a training-congruent memory bias for the ambiguous scenarios such that participants will be more likely to report memory distortions (or intrusions) that are congruent with their training condition. Finally, we assessed mood before and after training and after recall, mainly for the purpose of ascertaining whether changes in interpretation and recall might have been caused by changes in mood instead of by CBM-I.

Method

Participants

Fifty-eight undergraduate college students (male: 30/ female: 28) were recruited to participate in the study in exchange for course credit. Participants were randomly assigned to either the positive or negative training condition.

Questionnaires

Beck Depression Inventory (BDI-II). Severity of current depressive symptoms was assessed using this 21-item self-report measure. The BDI is a widely used depression scale with good psychometric properties (Beck & Steer, 1993; Beck, Steer, & Garbin, 1988), and correlations with clinician ratings of depression from .62 to .66 (Foa, Riggs, Dancu, & Rothbaum, 1993).

Mood ratings. To assess current mood participants were presented with multiple mood items (*disappointed*, *angry*, *sad*, *upset*, *discouraged*, *fearful*, *helpless*, *disgust*, *frustrated*, and *insecure*) and asked to indicate the degree to which they felt this way right now, on a scale of 1 (*not at all*) to 11 (*extremely*). Responses were averaged across all items to yield a single negative mood score ($\alpha = .85$).

Interpretation Training

Participants were presented with 10 blocks of 13 scenarios each in which they were asked to imagine themselves as the central character. In a scenario titled "Meeting a Friend," for example, participants were asked to picture themselves waiting at an empty bar to meet an old friend. Instructions and scenarios were taken from training studies by Mathews and Mackintosh (2000). Each scenario consisted of a title and two to three sentences and ended with a word fragment for participants to complete. Within each of the 10 training blocks, 8 training scenarios, 2 probe scenarios, and 3 filler scenarios were presented. For the training scenarios, each word fragment could be completed to produce only one possible solution, which disambiguated the meaning of the scenario according to the assigned training condition. Thus, for the positive training group, the completed fragment produced a positive outcome for the scenario, whereas for the negative training group the completed fragment produced a negative outcome. In probe scenarios, the word fragment disambiguated the sentence in the same way (either positive or negative) for all participants, regardless of training group. In filler scenarios, completion of the word fragments produced a neutral meaning. Examples can be found in previous training studies (e.g., Mathews & Mackintosh, 2000).

Before training, participants were told that for each trial, they would be shown a brief scenario ending with an incomplete word fragment. They were instructed to press the spacebar as soon as they were able to solve the word fragment. The latency of this key press was recorded. Following the key press, the scenario disappeared from the screen and participants then typed the completed word on the next screen. In the final segment of the trial, participants were presented with a simple comprehension question and responded by using "Y" (yes) or "N" (no). This comprehension question served to emphasize the valence of each scenario, as well as test participants' understanding of the text. Participants were given the opportunity to complete three practice trials before beginning the training to ensure their understanding of the task. The order of the training blocks and the order of the scenarios within the blocks were newly randomized for each participant.

Test Phase

In the test phase, participants were presented with 20 novel ambiguous scenarios, identical in structure to the ones they had viewed in the training phase. The main difference between the training and test scenarios was the fact that, although there was only one possible solution for the word fragment, the resolved word maintained the ambiguity of the preceding text and did not resolve the scenario in a positive or negative way. The scenarios were presented in random order. Again, participants were shown each scenario on the computer screen and were instructed to press any key as soon as they were able to solve the word fragment. After doing so, the scenario disappeared from the screen and they were asked to enter the completed word. Next, to maintain consistency, participants were presented with a comprehension question and were asked to indicate their answers with a "Y" or "N" response. Following their response, they were presented with the next test scenario. Unlike the comprehension questions during the training phase, these questions did not draw attention to the emotional implications of the scenario.

Interpretation test. Following a brief filler task, participants completed a computer task in which they were presented with the titles of the previously presented test scenarios. Each title was presented one at a time on the screen in random order. For each scenario title, participants were instructed to rate four sentences according to their similarity to the original scenario with the corresponding title (1, very different; 2, fairly different; 3, fairly similar; 4, very similar). In each case, two of these sentences were target sentences–a positive target that matched a positive interpretation of the original scenario (e.g., *You arrange to meet in a bar and your friend arrives late*) and a negative target that matched a negative interpretation (e.g., *You arrange to meet in a bar but your friend doesn't turn up*). The other two sentences were positive and negative foils, which were sentences with a generally positive or negative meaning that was unrelated to the ambiguous concept in the original scenario. These foil statements were included to assess broader valence effects of the training. The positive foil sentence assigned a generally positive meaning to the scenario, but was not based on any information provided by the original text (e.g., *Your friend wants to meet again but you don't have time*), while the negative foil sentence assigned a generally negative meaning but was not based on the original text (e.g., *Your friend tells you that she does not want to meet you*).

To assess interpretations of the test scenarios, each of the four sentences (per scenario) was presented one at a time under the scenario title. When each sentence appeared on the screen, participants were instructed to type the number corresponding to their rating of similarity to the meaning of the scenario. Once they entered their similarity rating, they were presented with the next sentence until they had provided ratings for all four sentences corresponding to that scenario title. The order of these sentences was newly randomized for each participant.

Recall task. Finally, participants were asked to recall details from the 20 test scenarios. The titles of the scenarios were presented in random order on the computer screen. When presented with each title, participants were instructed to recall aloud as many details as they could from the corresponding scenario. A key press initiated the next trial. Responses were audio-taped and later transcribed. Two independent raters were trained to code the transcriptions for whether each recalled scenario contained intrusions, or new ideas (yes/no), and if so, the valence of each intrusion (positive, negative, neutral). Once adequate levels of interrater agreement in the number and valence of intrusions were achieved ($r = .85$) using independent training scenarios, two raters who were blind to the experimental conditions categorized intrusions in each recalled scenario as belonging to one of three groups: negative (e.g., *everyone stares and laughs at you at the bar*), positive (e.g., *your friend arrives right as you walk in the door and is happy to see you*), or neutral (e.g., *you have a seat and wait at the bar*).

Overall Procedure

At the beginning of the session, participants were informed that they were participating in a study examining concentration and memory. Participants were assigned to complete either the positive or negative interpretation training on the computer, which lasted approximately 45 min. After the training phase, participants completed a 15-min word scramble filler task that was followed by the test phase. During the test phase, participants first read the set of 20 emotionally ambiguous scenarios and then completed another brief filler task, the Reverse Digit Span task from the Wechsler Adult Intelligence Scale-III (WAIS-III) before performing the interpretation and recall tests, in that order. Mood ratings were collected before the training, right after the training and at the end of the recall task. The BDI-II was administered at the end of the session, which lasted ~1.5 hr.

Results

Demographic Characteristics and Mood Ratings

Two participants failed to complete the BDI-II. Participants in the two groups did not differ in gender (positive group: 15F, 14M; negative group: 13F, 16M). The positive ($M = 8.9$, $SD = 7.9$) and negative ($M = 9.1$, $SD = 7.7$) training groups also did not differ in BDI scores, $t(54) < 1$. We compared mood ratings at three time-points: before the interpretation training (Time 1), after the interpretation training (Time 2), and after the recall task (Time 3), using a mixed-design ANOVA with training condition (positive vs. negative) as the between-subjects factor and time as the within-subjects factor. No significant effects were observed for group, $F(1, 56) = 2.18$, $p > .10$, time, $F(2, 112) < 1$, or time × group, $F(2, 112) < 1$.[1]

Interpretation Training

Two sets of analyses were performed to evaluate the effectiveness of the interpretation training. First, we calculated the total time to read each probe scenario and respond to the word fragment at the end during the training phase. During the second half of training, we expected to see that training groups would differ in their latencies for positive and negative probe scenarios in that the positive compared to the negative training group would respond faster to positive probe scenarios and the negative compared to the positive training group would respond faster to negative probe scenarios. Second, similarity ratings of the novel test scenarios were examined. We predicted higher similarity ratings for target statements corresponding to training condition, such that participants in the positive group compared to the negative group would rate positive target sentences as being more similar to the novel scenarios and participants in the negative group compared to the positive group would rate negative target sentences as being more similar to the novel scenarios. Effects that are not described in the results sections were nonsignificant with *p* values greater than .05. Significant effects qualified by significant higher order effects are not reported.

Probe response times. Reading and response times to the positive and negative probe scenarios were averaged for each half of the training. After accounting for outliers that exceeded the quartiles by more than three times the interquartile range, 0.2% of responses were eliminated. Mean latencies were entered into a mixed-model ANOVA with training group (positive vs. negative) as the between-subjects factor and probe valence (positive vs. negative) and time (first vs. second half) as within-subjects factors. The analysis yielded a significant three-way interaction among valence, time, and group, $F(1, 56) = 4.01$, $p < .05$, $\eta^2 = .07$. Mean response times are presented in Table 1.

To examine whether these interactions supported the effectiveness of our training, we conducted follow-up tests for response times in the second half of the training. First, we examined whether response times to positive and negative probe scenarios

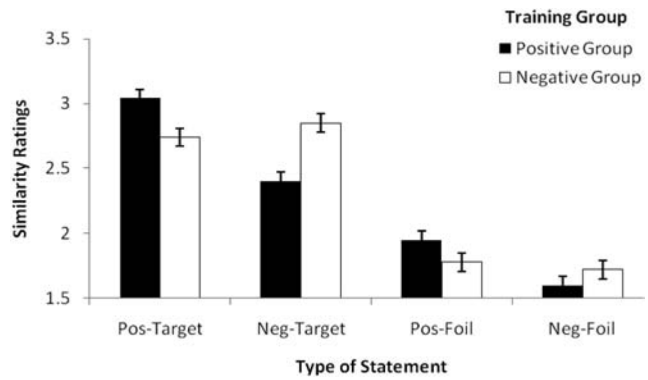

Figure 1. Mean similarity ratings for positive and negative target and foil statements when rating novel test scenarios separated by training group. Similarity ratings ranged from 1(*very different*) to 4 (*very similar*). Pos-target = positive target, neg-target = negative target, pos-foil = positive foil, and neg-foil = negative foil. Error bars represent 1 *SE*.

differed within training groups within the second half of the training trials. These analyses revealed no significant difference for the negative training group, $t(28) < 1$. The positive training group, however, exhibited a significant difference, $t(28) = 4.11$, $p < .001$. Individuals trained to make positive interpretations responded faster to positive compared to negative probes, illustrating the expected effect of interpretation training for the positive group.

Next, we examined whether we obtained significant differences between groups in their responses to positive or negative probes during the second half of training. There were no differences in response latencies to positive probes between the positive and negative training groups, $t(56) < 1$. The negative training group, however, was significantly faster to respond to negative probes, compared to the positive training group, $t(56) = 2.09$, $p < .05$.

Similarity ratings for test scenarios. To examine the effect of training on participants' interpretations of novel scenarios, similarity ratings for the test scenarios were entered into a mixed-model ANOVA with group (positive vs. negative training) as the between-subjects factor and valence of the statements (positive vs. negative) and type of statement (target vs. foil) as within-subjects factors. Analyses revealed the predicted three-way interaction of group, valence, and type, $F(1, 56) = 17.47$, $p < .001$, $\eta^2 = .24$. Follow-up analyses examining this three-way interaction were conducted separately for foil and target statements. Results of the follow-up tests revealed no significant training group differences in similarity ratings for both positive foils, $t(56) = 1.34$, $p > .10$, and negative foils, $t(56) < 1$. There were, however, significant between-groups differences for the target statements. As seen in Figure 1, participants in the positive training group chose higher similarity ratings for positive target statements than participants in the negative training group, $t(56) = 3.75$, $p < .001$. Additionally, participants in the negative training group compared to participants

[1] No significant correlations were found among mood ratings assessed after the training and any of the interpretation or memory measures (i.e., similarity ratings for positive and negative targets and positive, negative, and neutral intrusions).

Table 1
Mean Latencies (in seconds) to Read and Respond to Probe Scenarios in the Training Phase

	First half		Second half	
	Positive group *M* (*SD*)	Negative group *M* (*SD*)	Positive group *M* (*SD*)	Negative group *M* (*SD*)
Positive probe	14.68 (4.18)	15.51 (4.40)	15.07 (3.64)	16.19 (4.77)
Negative probe	16.27 (3.87)	16.13 (3.88)	18.32 (4.94)	15.50 (5.34)

Note. $N = 58$.

in the positive training group chose higher similarity ratings for negative target statements, $t(56) = 4.34$, $p < .001$. In summary, participants endorsed higher similarity ratings for target statements corresponding to their training condition.

Recall Task

The main goal of our study was to examine whether interpretation training affects participants' memory for the test scenarios. Thus, our main prediction was that the interpretation training would result in a corresponding memory bias in the free-recall task. We assessed the number and valence of memory distortions or intrusions (i.e., new details that the participants "recalled" that had never been part of the original scenarios). The training groups were compared on number of intrusions using a mixed-model ANOVA with training condition (positive vs. negative) as the between-subjects factor and valence of the intrusion (positive vs. negative vs. neutral) as the within-subjects factor. The results supported the predicted significant interaction between training group and intrusion valence, $F(2, 112) = 5.60$, $p < .01$, $\eta^2 = .09$. Although the groups did not differ in the number of reported neutral intrusions, $t(56) < 1$, there were significant group differences in both the number of positive intrusions, $t(56) = 4.60$, $p < .001$, and negative intrusions, $t(56) = 2.57$, $p < .01$. As illustrated in Figure 2, both groups produced significantly more neutral than positive intrusions [positive group: $t(28) = 3.41$, $p < .01$; negative group: $t(28) = 11.10$, $p < .001$]. Both groups also produced significantly more neutral intrusions than negative intrusions [positive group: $t(28) = 9.11$, $p < .001$; negative group: $t(28) = 6.19$, $p < .001$]. Most notably, the positive group "recalled" more positive intrusions than the negative group, $t(28) = 3.41$, $p < .01$, while the negative group "recalled" more negative intrusions than the positive group, $t(28) = 3.71$, $p < .01$. These results indicate that participants in each group reported more memory intrusions corresponding to the valence of their trained condition, suggesting that memory distortions result from interpretation biases.[2]

Discussion

These results support the proposition that biases in interpretation can be induced, and that induced interpretation biases result in corresponding biases in memory. Participants in the positive and negative training groups demonstrated memory biases in the final recall task that corresponded to their training condition. More specifically, when asked to recall details from novel, ambiguous scenarios, participants in each training group reported more intrusions (never-presented details) that corresponded to the valence of their initial interpretation training. Thus, participants in the positive training group compared to the negative training group were more likely to recall never-presented positive details whereas participants in the negative training group compared to the positive training group were more likely to recall never-presented negative details.

Findings from the current study replicate past research demonstrating effects of CBM-I (e.g., Mackintosh et al., 2006; Mathews & Mackintosh, 2000; Salemink, van den Hout, & Kindt, 2007; Yiend et al., 2005). These results include group differences in response latencies during interpretation training and in similarity ratings of statements expressing interpretations of the novel scenarios. CBM-I studies, however, have focused only on one cognitive bias at a time, even though researchers have suggested that cognitive biases likely interact and influence each other (e.g., Hirsch et al., 2006). Our recall results are in accordance with the tradition of research on constructive memory, which demonstrates that how events are initially interpreted affects how they are subsequently recalled. Importantly, our findings extend those of Hertel et al. (2008), who examined the relation between interpretation and memory biases in generalized social phobia (GSP). Hertel et al. demonstrated that intrusions during recall reflected the content of socially anxious interpretations of ambiguous scenarios, whereas we showed that the valence of such intrusions was consistent with the valence of CBM-I training. Given the evidence for memory biases in depression (Matt et al., 1992; Watkins, Mathews, Williamson, & Fuller, 1992), the increasing evidence for memory bias in anxiety when interpretation is taken into account (e.g., Hertel et al., 2008; Lundt & Ost, 1996), and the potential benefits from training positive biases on emotion regulation and stress reactivity, investigating the connection between interpretation and memory is a critical area for further exploration. The tendency to respond to negative events and mood states with rumination, for example, is an important risk factor for the onset of depression (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). People who ruminate repetitively think about past events and frequently start interpreting these events in a negative way. Indeed, rumination has been shown to strengthen mood-congruent memory

[2] Significant correlations among number of intrusions and similarity ratings for target statements for all participants are as follows: positive intrusions and positive targets, $r(58) = .29$, $p < .05$; positive intrusions and negative targets, $r(58) = -.35$, $p < .01$; negative intrusions and negative targets, $r(58) = .42$, $p < .001$. There were no significant correlations among intrusions and similarity ratings for target statements when examining each training group separately.

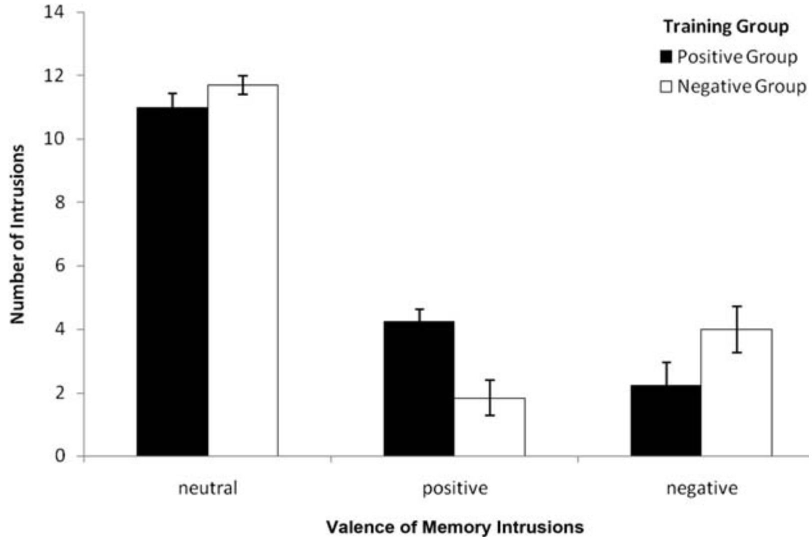

Figure 2. Mean number of positive, negative, and neutral memory intrusions (i.e., material that was not originally presented) made by each training group during the recall task. Error bars represent 1 *SE*.

biases (Lyubomirsky, Caldwell, & Nolen-Hoeksema, 1998). In contrast, the benefits of reappraisal as a more adaptive emotion regulation strategy may lie in its resemblance to positive interpretation training. Our findings suggest that the habitual use of rumination or reappraisal may have important consequences not only for acute emotional responding but also for how the emotion-eliciting event will be remembered and thereby affect emotional well-being in the future.

The present study is the first to find CBM-I effects on subsequent scenario recall, but it is not the first to investigate effects on tests of memory. Almost all previous CBM-I studies performed with scenarios assessed the training effects on interpretation by presenting "recognition" tests following the set of transfer scenarios. On these tests, as in the present procedure, participants rate the similarity of alternatives presenting possible interpretations to the content of the transfer scenarios. In effect, the participants are "recognizing" the meaning of the scenarios, because they must think back to the scenario to make the judgment. Our recall procedure extends this effect to a more active, reconstructive task of recalling the scenario as it was initially presented. Clearly, participants might have been assisted in wording their recall by having read the previous statements during the recognition test. However, it is important to realize that all participants read statements expressing each type of interpretation, so if the assistance occurred, it did not confound the effect.

The second investigation of CBM-I effects on scenario recall was recently conducted by Salemink, Hertel, and Mackintosh (2010), who trained biases after the reading of the scenarios to be recalled in an effort to discover whether the recall of prior events could be modified by later acquired biases. This effort produced evidence of biased recall of the participants own interpretation of the scenarios, but not the scenarios themselves. The lack of effect on scenario recall was predicted on the basis that recall intrusions arise from imagery processes operating during initial interpretations (see Hertel et al., 2008, Experiment 2; Hirsch et al., 2006).

Though prior training studies have obtained effects of training for both positive and negative training groups (Mathews & Mackintosh, 2000; Salemink et al., 2007; Yiend et al., 2005), some of our measures (i.e., response latencies) indicate that the positive training may have had stronger effects than the negative training. We note, however, that our response times for fragment completion on probe trials included the reading time for the scenario, unlike most training studies. Thus, the response times reported in this study cannot be readily compared to previous training studies and may be less sensitive. Even so, the negative training group compared to the positive training group was faster to respond to negative probes, and the positive training group was faster to respond to positive compared to negative probes. In addition, the finding that both training groups exhibited the expected training-congruent pattern in their similarity ratings supports the proposition that both training conditions were indeed effective.

Similar to other studies (e.g., Mackintosh et al., 2006, Experiment 1), we did not find congruent effects of training on anxiety, suggesting that the training itself may not have direct effects on mood/anxiety. However, our primary motivation for assessing mood before and after training and after recall was to assess if changes in interpretation and recall were a result of mood instead of the interpretation training itself. More research exploring the causal relationship between interpretive biases and mood is needed to better explore the effects of the training on affect. Some recent research has shown CBM-I effects on reactivity to a subsequent stressor (see MacLeod, Koster, & Fox, 2009).

We should point out limitations of this study. All of our participants received some form of training and we did not include a no-training control group. It is therefore difficult to conclude whether the obtained group differences in memory intrusions are because of changes induced by the negative or the positive training or both. However, the between-groups differences in the valence of memory biases suggest that both training conditions were effective. In addition, we did not assess pretraining biases in interpretation or memory. However, the lack of significant group differences in responses to probes in the first half of the training (and in BDI scores) is reassuring in this regard.

Alternative explanations of our results point to mood and the order of our tasks. First, the majority of research on memory bias attributes changes to mood, so mood might possibly be responsible for the changes in this experiment. Clearly, this account does not apply, because measures of mood did not change as a consequence of training and were not related to measures of memory. Second, our method included an assessment of interpretation bias before recall bias, so perhaps that assessment itself played a causal role. The interpretation task was included so that we could assess replication of previous findings (e.g., Grey & Mathews, 2000; Mathews & Mackintosh, 2000; Yiend et al., 2005). If we had measured recall first, several problems would have presented themselves. During recall, participants are given more time to elaborate on their memory of the previously presented scenarios; therefore, their subsequent similarity ratings would primarily assess how participants recalled the descriptions during recall, rather than how they interpreted the situation initially. In the current design, however, the interpretation task is presented as a brief exercise in which participants are asked to quickly indicate similarity ratings, and less time for elaboration is allowed. In addition, both groups are exposed to the same four sentences (2 targets and 2 foils); hence, group differences in recall cannot be explained by differences in exposure to statements in the interpretation task. The main constraint that test order offers these results pertains to external validity. It is perhaps the case that explicit interpretation is necessary to obtain biases in distorted remembering. This possibility deserves investigation in future research. Additionally, it is possible that other presented information during the similarity ratings task may have been incorporated into participants' memory for the original scenario, thus affecting results of the recall and appearing as "new" information. However, all participants, regardless of training group, were presented with the same set of four sentences during the similarity rating task. Thus, our training group differences in intrusions in the recall task cannot be fully explained by having participated in the earlier recognition task.

While some studies have begun to examine the effects of retraining on preexisting biases (Mathews, Ridgeway, Cook, & Yiend, 2007; Salemink, van den Hout, & Kindt, 2009) and in clinical samples (Beard & Amir, 2008), it is important to continue to examine the efficacy of cognitive bias modification in these populations and to determine whether the effects can extend to recall. In a similar vein, future studies should examine the impact of manipulating interpretation and memory biases on mood and emotional vulnerability, using both self-report and behavioral measures. Ultimately, more research on the durability of the effects of the training, both on cognitive biases, as well as on mood symptoms, would provide important additional information regarding the utility of the training in clinical settings for both the prevention and treatment of emotional disorders. Furthermore, as suggested by MacLeod et al., (2009), more research is needed to better understand the mechanisms that drive the modification of biases in cognition.

Interpretation and memory biases affect emotion regulation in various ways. They can influence judgments of the frequency of positive and negative events and of the likelihood that these types of events occur in the future. Memory biases have also been associated with lowered self-esteem, and increased levels of negative affect and hopelessness (MacLeod & Campbell, 1992). Increased accessibility of negative material and difficulties recalling mood-incongruent material may interfere with the use of effective mood regulation strategies. These difficulties in effectively managing negative mood may be an important mechanism by which memory biases affect the maintenance and recurrence of depressive episodes (Nolen-Hoeksema, 2000; Nolen-Hoeksema & Larson, 1999; Roberts, Gilboa, & Gotlib, 1998). Increased accessibility and recall of positive material, on the other hand, is related to higher levels of well-being (Charles et al., 2003). Manipulating biases in memory and interpretation may, thus, affect mood and emotional vulnerability following stressful experiences, potentially reducing the risk for onset and recurrence of emotional disorders. Future studies are needed to extend these findings to clinical populations and to examine the durability of the training effects. Given the critical role of memory biases in the development and maintenance of emotional disorders, the ability to manipulate interpretation biases thereby changing memory for events could hold great promise for the prevention and treatment of these disorders and provide more insight into the functional role of cognitive biases in emotional disorders.

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