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Effect of Cognitive Bias Modification-Memory on Depressive Symptoms and Autobiographical Memory Bias: Two Independent Studies in High-Ruminating and Dysphoric Samples

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Effect of cognitive bias modification-memory on depressive symptoms and autobiographical memory bias: two independent studies in high-ruminating and dysphoric samples

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ABSTRACT

Memory bias is a risk factor for depression. In two independent studies, the efficacy of one CBM-Memory session on negative memory bias and depressive symptoms was tested in vulnerable samples. We compared positive to neutral (control) CBM-Memory trainings in highly-ruminating individuals ($N = 101$) and individuals with elevated depressive symptoms ($N = 100$). In both studies, participants studied positive, neutral, and negative Swahili words paired with their translations. In five study–test blocks, they were then prompted to retrieve either only the positive or neutral translations. Immediately following the training and one week later, we tested cued recall of all translations and autobiographical memory bias; and also measured mood, depressive symptoms, and rumination. Retrieval practice resulted in training-congruent recall both immediately after and one week after the training. Overall, there was no differential decrease in symptoms or difference in autobiographical memory bias between the training conditions. In the dysphoric but not in the high-ruminating sample, the positive training resulted in positive autobiographical bias only in dysphoric individuals with positive pre-existing bias.

We conclude that one session of positive retrieval-based CBM-Memory may not be enough to yield symptom change and affect autobiographical memory bias in vulnerable individuals.

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Depression is characterised by preferential processing of negative information, at the expense of neutral and positive information (Gotlib & Joormann, 2010; Mathews & MacLeod, 2005). This biased information processing is found in different cognitive domains. In depression, the most consistent evidence exists for a negative memory bias (Gaddy & Ingram, 2014; Mathews & MacLeod, 2005; Matt, Vazquez, & Campbell, 1992). A negative memory bias entails the preferential recall of negative compared to positive information, and can be found for autobiographical details, such as recent events, as well as for lexical material (Gotlib & Joormann, 2010). For example, a negative memory bias may consist of recalling romantic rejection but not acceptance, or of recalling the word "lonely" but not "happy". This negative memory bias is considered not only a symptom, but also a risk factor for depression onset and recurrence (Beck, 1964, 2005; De Raedt & Koster, 2010). Specifically, research has shown that negative memory bias is related to genetic risk for depression (e.g. Vrijsen, Tendolkar, et al., 2015; Vrijsen, Vogel, et al., 2015), that it is apparent in the children of depressed mothers (e.g. Taylor & Ingram, 1999), and that this

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memory bias remains after remission of depression (e.g. Vrijsen et al., 2014). Moreover, negative memory bias can predict the longitudinal course of depressive symptoms (Johnson, Joormann, & Gotlib, 2007).

Computerised trainings have been developed based on this causal relation between cognitive biases and emotional symptoms, a technique termed Cognitive Bias Modification (CBM). By training the cognitive processing of specific emotional information, CBM has been able to produce changes in biased processing (e.g. Baert, De Raedt, Schacht, & Koster, 2010; Cristea, Kok, & Cuijpers, 2015). However, the evidence for CBM affecting depressive symptoms is mixed and replication is often lacking (see review of meta-analyses, Jones & Sharpe, 2017; and also Cristea, Kok, & Cuijpers, 2017; Grafton et al., 2017). However, it is important to note that in individuals with elevated depressive symptoms, most CBM studies have attempted to change attention and interpretation biases (Jones & Sharpe, 2017).

Based on the robust role of negative memory bias in depression (see e.g. De Raedt & Koster, 2010; Gotlib & Joormann, 2010), CBM-Memory emerges as a promising new approach. There are currently few examples of emotional memory trainings for depression. A recent study in depressed patients ($N = 27$) aimed to directly change the quality of positive autobiographical memory by comparing a positive to a neutral autobiographical memory training condition (Arditte Hall, De Raedt, Timpano, & Joormann, 2017). The positive training resulted in increased specificity of autobiographical memory and better mood regulation. However, this study did not examine transfer to depressive symptoms or other memory processes. In another attempt to explore the clinical application of CBM-Memory, Vrijsen, Hertel, and Becker (2016) developed a training designed to model repetitive retrieval of emotional information, an important aspect of depressive rumination (Koster, De Lissnyder, Derakshan, & De Raedt, 2011; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This study found that this retrieval-based CBM-Memory affected mood and that the training effect transferred to autobiographical memory bias.

As said, the CBM-Memory training of Vrijsen et al. (2016) modelled rumination. Rumination is implicated in emotional memory bias (e.g. Hertel, 2004; Koster et al., 2011): In depressive rumination, the same negative event is retrieved from memory and brought to mind over and over. Depressive rumination is a verbal process (Nolen-Hoeksema et al., 2008; Watkins, 2008). Because each episode of retrieval facilitates future recall (Roediger & Butler, 2011), ruminating over a negative event strengthens the negative memory bias. Moreover, repeated retrieval is a powerful learning strategy producing large gains in long-term retention (Karpicke & Roediger, 2008). Retrieval practice also promotes transfer of the learned information to other contexts (Karpicke & Roediger, 2008; Roediger & Butler, 2011). Accordingly, integrating retrieval-based learning in CBM is an approach that can result in lasting change in cognitive processing and transfer to other tasks. By repeating retrieval of positive information in CBM-Memory, ruminative thinking is opposed, and long-term retention of the learned material is facilitated. Moreover, positive memory schemata are repeatedly activated and thereby strengthened (Beck, 1964, 2005). This is turn is expected to result in overall facilitated retrieval of positive information, or, more general positive memory bias also for e.g. autobiographical information.

In the CBM-Memory training, Vrijsen et al. (2016) repeatedly prompted retrieval of emotional words in non-depressed Dutch individuals. Positive and negative Swahili-Dutch word pairs were presented in each of three training blocks. After a brief distraction, participants were prompted by the Swahili cues (i.e. words from a language individuals did not know = cues without meaning to the participant) and asked to type the correct Dutch translations (i.e. the individuals' native language = meaningful emotional targets). Only positive words were presented in the retrieval phase of the positive (therapeutic) training condition and only negative words in the condition that simulated depressive rumination. Participants in the no-training control condition merely studied the word pairs. Training-congruent recall was observed immediately after the training as well as one week later. Both retrieval-training conditions outperformed the no-training condition. Moreover, the training effect transferred to mood and individuals with more positive recall after the training had a higher chance of recalling a positive autobiographical event as a real-life measure of memory bias.

Hertel, Maydon, Cottle, and Vrijsen (2017) provided evidence underscoring the idea that retrieval practice is indeed related to ruminative processes. In an unselected sample and conforming to the procedures employed in the previous study (Vrijsen et al., 2016), they found that four blocks of retrieval-based positive or negative training resulted in training-congruent

recall. When stratifying for trait rumination, they found that high-ruminating individuals in the positive training condition recalled as many negative Swahili translations as positive on the immediate test, but on the delayed test, only the positive-practice effect was obtained. Moreover, this effect transferred to mood state; ruminators who practiced positive retrieval reported lower levels of negative mood state than did those in the negative training condition. These results suggest that systematic practice in recalling positive events is a process that might counter rumination.

The previous studies in unselected samples (Hertel et al., 2017; Vrijsen et al., 2016) indicate that retrieval-based CBM-Memory affects mood and transfers to autobiographical memory bias by opposing the depressotypic ruminative thinking style. We therefore wanted to test the clinical applicability of the training in two samples: one dysphoric and the other specifically endorsing high levels of rumination. Hence, the efficacy of one session of CBM-Memory for affecting memory bias, depressive symptoms, and rumination was tested in two independent, vulnerable samples.

To further develop this intervention, we made several changes to the procedures used previously (Hertel et al., 2017; Vrijsen et al., 2016). First, in line with other studies in samples vulnerable to depression (e.g. Vrijsen et al., 2014), a negative mood induction was used before the training session to activate the negative processing style (Segal & Ingram, 1994) and reduce variation in mood state levels. Second, we increased the number of training blocks to five in order to increase training effects. Third, we included a neutral training control condition along with the positive (therapeutic) condition (in line with Arditte Hall et al., 2017), because (1) using a negative training condition as a comparison condition is not ethical in vulnerable samples and (2) it provides a stringent test of the efficacy of the positive condition. Fourth, to examine the strength of the transfer to autobiographic memory bias, we included two autobiographical memory questions: for retrieval of a recent and lifetime event. Finally, guided by the aim of personalising interventions and evidence suggesting that bias at baseline may moderate CBM efficacy (Boettcher, Hasselrot, Sund, Andersson, & Carlbring, 2014; Calamaras, Tone, & Anderson, 2012), we investigated whether pre-experimental self-referent memory bias would moderate the effect of one session of CBM-memory on autobiographical memory bias.

We expected that the positive training would result in a stronger decrease of symptoms and relatively more positive autobiographical memory bias than the neutral training, because the positive training was anticipated to best counter the negative processing style. Secondly, we expected that the strongest transfer to autobiographical memory bias for individuals with pre-existing negative bias would occur in the positive training condition. In line with the previous CBM-Memory studies, we further expected increased recall for training-congruent word pairs both immediately after the training, and one week later. We also expected the positive training to repeatedly activate and hence strengthen the positive cognitive schema while reducing the activation of negative cognitive schema (Beck, 1964, 2005), resulting in a greater decrease in the recall of (untrained) negative words, compared to the neutral training condition.

Study 1

Method

Participants

Undergraduate students from the Radboud Unversity Nijmegen, The Netherlands, were screened online for rumination using the Ruminative Response Scale (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003; Dutch version by Raes & Hermans, 2007) and were invited to the laboratory for participation if their total RRS score was ≥ 40. We based this cut-off on a prevention trial in high-ruminating and high-worrying adolescents and adults (i.e. the 75th percentile in the study of Topper, Emmelkamp, Watkins, & Ehring, 2017). Table 1 presents the sample characteristics. A total of 101 participants were randomly assigned to one of the two training conditions: positive memory training ($n = 51$) and neutral memory training ($n = 50$). Based on the condition-rumination subgroup effect on positive mood in the previous study (Hertel et al., 2017), we needed an $N = 40$. However, because we expected a smaller effect size when comparing a positive to a *neutral* (instead of negative) training condition, we pragmatically chose $N = 100$ to have sufficient power.

The two groups did not differ in age or gender identification (see Table 1). They also did not significantly differ on the following baseline symptom levels: Depressive symptoms (measured by the Beck Depression Inventory, BDI-II; Beck, Steer, & Brown, 1996; Dutch version by Van der Does, 2002), anxiety symptoms (measured by the Beck Anxiety Inventory, BAI; Beck, Epstein, Brown, & Steer, 1988; Dutch version evaluated by Muntingh et al., 2011), state

Table 1. Percentages or means (Standard Deviations) on demographic and assessment measures including baseline group comparisons.

	Training condition		
	Positive	Neutral	
Study 1	($n = 51$)	($n = 50$)	$t(99) =$
Gender, % female	72%	70%	$\chi^2(1) = 2.82$, $p = .093$
Age, years	23 (4.8)	22 (6.2)	0.14, $p = .893$
BAI	10.6 (8.7)	10.7 (8.1)	0.72, $p = .975$
MRSI: *S1 Baseline*	23.9 (6.3)	25.2 (6.6)	0.58, $p = .335$
S1 Post-training	22.4 (5.9)	22.8 (6.8)	
S2 Follow-up	22.3 (6.4)	22.4 (5.9)	
BDI-II: *S1 Baseline*	10.2 (8.5)	11.8 (9.2)	0.43, $p = .353$
S2 Follow-up	10.1 (8.1)	13.1 (9.1)	
RRS: *S1 Baseline*	52.2 (12.3)	55.4 (13.2)	0.95, $p = .211$
S2 Follow-up	50.7 (10.4)	53.2 (14.0)	
Study 2	($n = 46$)	($n = 54$)	$t(98) =$
Gender, % female	90%	78%	$\chi^2(1) = 0.02$, $p = .880$
Age, years	19 (1.4)	19 (1.2)	0.85, $p = .948$
BAI	16.6 (9.1)	18.7 (8.5)	0.93, $p = .236$
MRSI: *S1 Baseline*	32.1 (6.2)	33.1 (7.2)	0.42, $p = .509$
S1 Post-training	39.0 (6.6)	38.0 (7.9)	
S2 Follow-up	29.2 (6.3)	28.4 (8.9)	
BDI-II: *S1 Baseline*	22.1 (7.4)	22.5 (7.5)	0.83, $p = .804$
S2 Follow-up	20.9 (9.4)	20.8 (9.6)	
RRS: *S1 Baseline*	54.9 (10.3)	56.1 (11.0)	0.58, $p = .566$
S2 Follow-up	51.5 (10.9)	52.4 (11.3)	

Note: BAI refers to the Beck Anxiety inventory, MRSI to the score on the Momentary Ruminative Self-Focus Inventory, BDI-II refers to the score on the Beck Depression Inventory, RRS to the total score on the Ruminative Response Scale. S1 refers to Session 1, S2 refers to Session 2.

rumination (measured by the Momentary Ruminative Self-Focus Inventory, MRSI; Mor, Marchetti, & Koster, 2013), and trait rumination (measured by the RRS; Treynor et al., 2003; Dutch version by Raes & Hermans, 2007). All participants provided informed consent.

Materials

The study consisted of two sessions: The first session (Session 1) included training and took place in the lab; a second session (Session 2) took place online one week later. A schematic overview of the study procedure is depicted in Figure 1.

Questionnaires. The 21-item BDI-II (Beck et al., 1996) assesses the severity of a range of affective, somatic and cognitive symptoms of depression. Each item's response scale ranges from 0 to 3; a maximum score of 63 is thus possible. Participants completed the Dutch version, which has acceptable reliability and validity (Van der Does, 2002). The internal consistency was excellent in the current sample ($\alpha = .90$).

The 21-item BAI (Beck et al., 1988) assesses the severity of a range of anxiety symptoms; items are scored from 0 to 3 and a maximum of 63 is possible. The BAI is a reliable and valid instrument (Fydrich, Dowdall, & Chambless, 1992). The internal consistency was excellent in the current sample ($\alpha = .90$).

The MRSI is a six-item questionnaire to assess state rumination (Mor et al., 2013). Participants were asked to indicate their degree of agreement on a 7-point scale that ranges from 1 "strongly disagree" to 7 "strongly agree" with a maximum total score of 42. The MRSI has shown good internal reliability and concurrent validity (Mor et al., 2013). This scale was found to have acceptable reliability in the current sample ($\alpha = .79$).

The RRS (Treynor et al., 2003) is a self-report questionnaire to investigate rumination. The validated Dutch adaptation consists of 26 items (Raes & Hermans, 2007). Participants indicate how often they engage in responses to a depressed mood that are focused on the self, symptoms, or consequences of the depressed using a 4-point scale that ranges from 1 "almost never" to 4 "almost always", with a maximum total score of 104. In the current sample, the internal consistency reliability was excellent ($\alpha = .91$).

Pre-existing memory bias. Before the training, memory bias was assessed using the Self-Referent Encoding Task (SRET; Derry & Kuiper, 1981; Hammen & Zupan, 1984). Twenty-four Dutch adjectives were

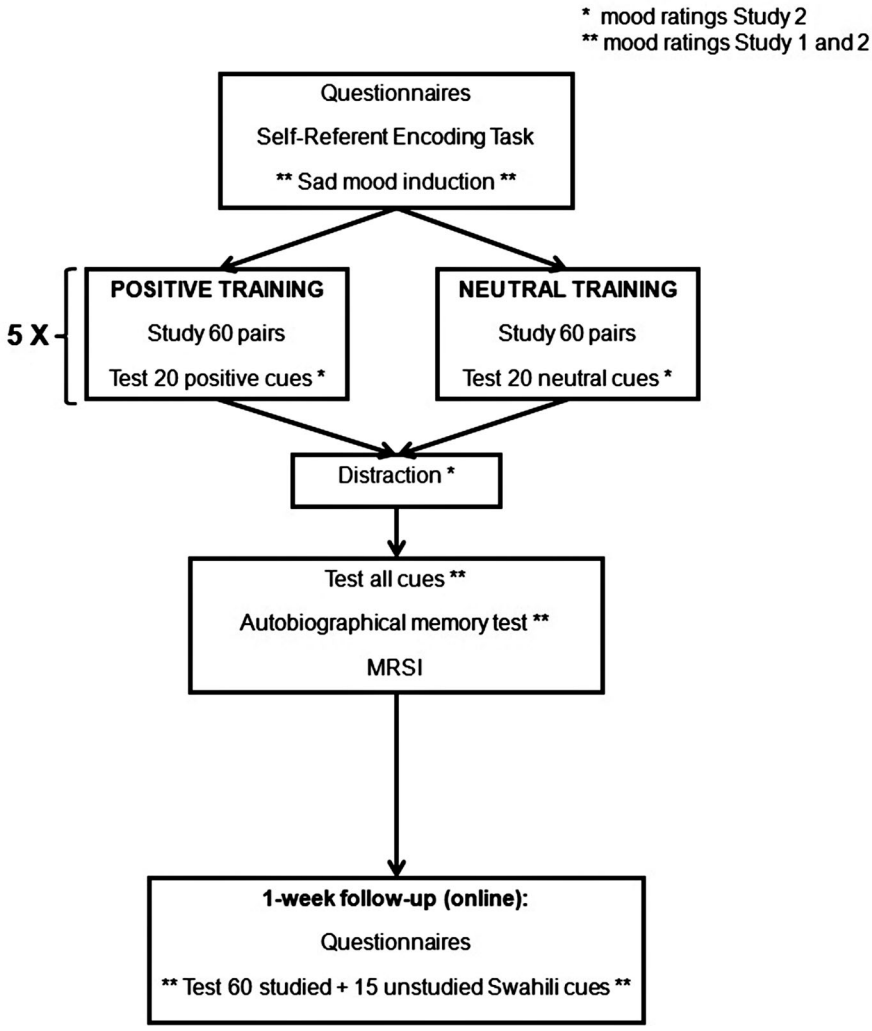

Figure 1. Schematic overview of the experiment. Studies 1 and 2 were identical. Pairs consisted of Swahili cues and English translations as targets with positive, neutral, or negative meaning.

selected from the Dutch translation of the Affective Norms for English Words (ANEW; Bradley & Lang, 1999); half were positive and half negative in valence. Each adjective was individually presented for 8,000 ms maximum; during the display, participants indicated by button press if the adjective described them or not. After all adjectives were judged, participants were distracted with a hard copy of Raven's Progressive Matrices (Raven, 1958) for 2 min and then given 3 min to type in all of the words they remembered. To calculate the positive memory bias score, we divided the number of positive adjectives that were endorsed as self-descriptive and subsequently recalled by the total number of positive and negative adjectives that were endorsed as self-descriptive (in line with, e.g. Van Oostrom et al., 2012; Vogel et al., 2014; Vrijsen, Tendolkar, et al., 2015). The same was done for the negative words that were endorsed and recalled to calculate the negative memory bias score.

Mood induction. Participants underwent a mood induction to trigger depressotypic processing. A 6 min section of the orchestral introduction by Prokofiev entitled "Russia Under the Mongolian Yoke" (1934) was played at half speed (following Clark & Teasdale, 1985), and we instructed participants to let the sadness of the music influence their mood and to try to maintain that mood state.

Mood ratings. 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?") were assessed throughout the two sessions. Each question was followed by a 9-point Likert scale ranging from "not at all" to "extremely". This is a reliable, simple, and rapid method to assess affective states (Abend, Dan, Maoz, Raz, & Bar-Haim, 2014).

Training. The training consisted of five blocks, each with a study phase and a test phase. In the study phase, participants viewed 60 Swahili-Dutch word pairs (with 20 pairs having a positive, 20 a neutral, and 20 a negative meaning), each presented in white in the middle of a black computer screen for 10 s, with a 500-ms interstimulus interval. The Dutch words were selected on valence strength ($M = 13.0$ for positive, $M = 8.3$ for neutral, and $M = 3.0$ for negative words (range = 0–15 varying from "very negative" via "neutral" to "very positive"; from the Dutch translation of Affective Norms for English Words (ANEW; Bradley & Lang, 1999) and matched across the valence categories on length.

The order of the words was pseudo-randomized, with the constraint that no more than two words of the same valence were presented consecutively; all participants viewed the words in the same order. Participants were instructed to memorise the word pairs. After a 30 s distraction (by simple arithmetic calculations that appeared on-screen, e.g. "2 + 4 = … ") to prevent rehearsal, the test phase began. Participants were presented with the 20 training-congruent (positive in the positive condition and neutral in the neutral training condition) Swahili words. The Swahili words were presented for 8 s each in the same order as they had been shown during the study phase. Participants were instructed to type in the Dutch translation below the Swahili word. No direct feedback on performance was given, although the participants saw the correct translations again during the subsequent study phase.

Recall assessments. Both immediately after the training (Session 1), and one week later (Session 2), recall of all 60 translations was tested by presentation of the Swahili words on the computer screen. The words were presented for 10 s each during Session 1 and for 15 s each during Session 2. Swahili cues were presented in the same order as during training. As in the test phase of the training blocks, participants were instructed to type the correct Dutch translation.

Fifteen additional Swahili words were selected as a measure of general recall bias in memory intrusions. Upon presentation of an unstudied Swahili cue, participants produced either a learned Dutch word that was not linked to that cue or another, unlearned Dutch word. These unstudied Swahili words were not differentiated from the studied words in any way. The valence of these words (these memory intrusions) is an index for general recall bias. In Session 2, these words were intermixed with the previously studied Swahili words, although the original words were presented in the same order as during training. The number of positive, neutral, and negative memory intrusions (false recall) was counted per participant.

Autobiographical recall. Following the recall test, we collected autobiographical recall of two events. First, participants were asked to recall and then type the description of a personal event from the day before that made an impression on them, and to identify the corresponding feeling. They were told that the event "can be a small thing", as long as it evoked a feeling. Second, participants were asked to type the description of an important lifetime event. Here they were told that it could be something that happened recently, or something that happened in the distant past, as long as it evoked a feeling from them. Instructions were deliberately simple and broad to increase the odds of transfer of training (Hertel & Mathews, 2011). Both recent and lifetime event descriptions were rated by two independent raters blind to the training conditions. The raters indicated whether each description was positive, negative, or neutral/unclear/non-emotional. Inconsistent scores were resolved by a third rater. Kappa > .94, $p < .001$ for both the recent and lifetime event descriptions.

Procedure

At the start of Session 1, participants completed the questionnaires (MRSI, BDI-II, BAI, RRS, in that order), followed by the SRET and the mood induction. The training followed automatically. A second assessment of state rumination with the MRSI followed the fifth training block. Then, prior to the test of all Swahili translations, participants attempted to solve more Raven's Progressive Matrices for 4 min, to eliminate possible mood effects and recency effects from practice. After the distraction, recall of all 60 translations was tested in a single block, followed by the autobiographical memory recall assessment.

Exactly one week after Session 1, participants received an email with a unique link to the online

follow-up task in LimeSurvey (Schmitz, 2012). We used this follow-up procedure to assess the transfer of training to a different, ecologically-valid context. At this timepoint, participants filled out the MRSI, the BDI-II and the RRS questionnaires. Then they were presented with 75 (60 studied and 15 new) Swahili words and instructed to type each translation within a 15 s window.

As indicated by asterisks on Figure 1, mood state during Session 1 was assessed after the SRET (before the mood induction), and following the mood induction, the test of all 60 translations, and the autobiographical memory test. In Session 2, mood was assessed after the questionnaires and at the end of the session.

Statistical analyses

Mixed-design ANOVAs were used to compare the training conditions on the recall of positive, negative, and neutral translations, as well as on depressive symptoms, rumination, and mood. Logistic regression models were used to examine the transfer of the training to autobiographical recall and memory intrusions.

For the main outcomes of depression and autobiographical memory recall, *post hoc* Bayesian analyses were conducted. Specifically, Bayes Factors (BF) were calculated to quantify the support for the effects of interest (as recommended by e.g. Dienes, 2014; Wagenmakers, 2007; Wagenmakers, Morey, & Lee, 2016). These can either suggest inconclusive findings (i.e. equal support for alternative and null hypotheses), or provide evidence in favour of the null hypothesis (e.g. treatments are equivalent on the outcome of interest). For example, a BF of 10 suggests the alternative hypothesis is 10 times more probable than the null hypothesis, a BF of 1 suggests hypotheses are equally supported by the data, and a BF of 0.10 (i.e. 1/10) suggests the null hypothesis is 10 times more probable than the alternative, indicating that treatments are equivalent. This allows for the interpretation of BFs as continuous indicators; additionally, some conventions have been suggested: (1) strong ($BF > 10$) or moderate ($3 \leq BF \leq 10$) evidence in favour of the alternative hypothesis; (2) inconclusive results ($0.33 < BF < 3$); or (3) strong ($BF < 0.10$) or moderate ($0.10 \leq BF \leq 0.33$) evidence in favour of the null (Lee & Wagenmakers, 2014). In the current analyses, the strength of the evidence in favour of (or against) a treatment effect on the depression outcome was evaluated by comparing the full model to the model without the condition-by-time interaction in a Bayesian ANOVA conducted in JASP (Version 0.8.1.1). For autobiographical memory BFs were calculated by comparing Bayesian Information Criteria (BIC) between logistic regression models of increasing complexity using a recommended formula (Wagenmakers, 2007).

Results

Recall

To examine whether the training indeed created a differential recall of emotional information, both at the immediate and the delayed recall test, the number of correctly recalled translations was submitted to a mixed-design ANOVA, with a between-subjects factor for practice condition and within-subject factor for valence (positive, neutral, or negative word meanings). Three participants did not complete the delayed recall test. Figure 3 presents the results. As predicted, the condition-valence interaction was significant both for the immediate and the delayed memory test, $F(2,98) = 68.95$, $p < .001$, $\eta_p^2 = .59$ and $F(2,95) = 57.59$, $p < .001$, $\eta_p^2 = .55$, respectively. A series of *t*-tests showed that the positive training produced the highest correct recall of positive words, and the neutral training condition showed the highest successful recall of neutral words on both tests, all $p < .001$. There was no significant difference between the conditions on recall of negative words on both the immediate and delayed test, $t(99) = 0.86$, $p = .393$ and $t(96) = 0.10$, $p = .922$, respectively. As expected, the training created differential recall of the emotional target words that lasted at least one week. However, positive training did not reduce the number of negative translations recalled, compared to neutral training, contrary to our prediction.

Presenting the words in the same order to all participants during training and testing facilitated successful retrieval but introduced a potential order effect. We therefore assessed whether each answer to each new Swahili cues in Session 2 was in fact the correct translation of the Swahili word that would appear next. This was true for only 0.2% of the intrusions (3 out of 15 intrusions × 101 participants = 1515 possible intrusions). Hence, it could be ruled out that the recall results reflect serial learning.

Mood induction

Positive and negative mood ratings were separately submitted to a mixed-design ANOVA, with a between-subjects factor of practice condition (positive

vs. neutral) and a within-subjects factor of timing of the ratings (pre vs. post mood induction). Because the mood induction occurred prior to the training, we expected and found that the interaction was not significant for either type of ratings, $F(1,99) = 1.89$, $p = .172$, $\eta_p^2 = .02$ for negative mood and $F(1,99) = 3.83$, $p = .053$, $\eta_p^2 = .04$ for positive mood. As expected, only the main effect of time was significant for both the negative and positive mood ratings, $F(1,99) = 77.43$, $p < .001$, $\eta_p^2 = .44$ and $F(1,99) = 44.76$, $p < .001$, $\eta_p^2 = .39$, respectively. Negative mood increased and positive mood decreased similarly across conditions; see Figure 2 for the means.

Transfer effects of the training on depressive symptoms, rumination, and mood

Table 1 reports descriptive statistics for the BDI-II, MRSI, and RRS at both sessions. To assess whether the conditions of retrieval practice yielded differential effects on depressive symptoms and on rumination, the condition-by-time (Session 1 vs. Session 2) interactions in BDI-II scores and RRS total scores were evaluated and found to be statistically nonsignificant; for BDI-II $F(1, 99) = 2.30$, $p = .139$, $\eta_p^2 = .02$ and for the RRS $F(1, 99) < 1.0$, $p = .657$, $\eta_p^2 < .01$. The main effect of time was not significant for the BDI-II, $F(1, 99) = 2.17$, $p = .144$, $\eta_p^2 = .02$. The main effect of time was, however, significant for the RRS, $F(1, 99) = 5.15$, $p = .025$, $\eta_p^2 = .05$. There was a small but significant decrease in trait rumination from the beginning of Session 1 to Session 2 across both conditions.

State rumination was measured three times using the MRSI: at the beginning of Session 1, immediately following training, and at the beginning of Session 2. The condition-time interaction was not significant, $F(2, 98) < 1.0$, $p = .623$, $\eta_p^2 = .01$, but the main effect of time was significant, $F(2, 98) = 8.03$, $p = .001$, $\eta_p^2 = .14$. State rumination decreased from the beginning of Session 1 to post-training in both conditions ($p = .001$ for paired sample t-test), and remained stable from post-training to Session 2 ($p = .644$).

Mood ratings were submitted to a mixed-design ANOVA, with practice condition as the between-subjects factor, and rating valence (positive or negative) and time of measurement as within-subjects factors (post-mood induction, post-immediate test, post-autobiographical memory test, pre-delayed test, post-delayed test). Figure 2 illustrates the means. The only significant interaction effect was shown by the valence-by-time interaction, $F(4,93) = 20.63$, $p < .001$, $\eta_p^2 = .47$. An inspection of the means suggests that positive mood increased and negative mood decreased in both conditions and in both sessions. No effect involving the factor for retrieval-practice condition was significant, all $p > .21$.

Transfer of the training effects to other memory processes

Autobiographical recall. Strongest training effects were expected in individuals with more negative compared to positive memory bias at baseline. Baseline memory bias data was missing for four participants. Additionally, one participant did not recall any words correctly on the SRET and was excluded from these analyses, because the participants likely did not follow instructions. Participants were divided into two groups based on their memory bias score on the SRET: one group had more positive relative to negative bias ($n = 78$), and the second group had more or equal negative to positive bias ($n = 18$). The numbers of participants per condition and pre-existing bias subgroup are presented in Figure 4.

The autobiographical recall variable was coded as positive or negative. For one participant's lifetime event description, the raters could not determine whether the event was positive or negative because the description was unclear. This resulted in a sample of $n = 96$ for the analyses on the recent event description, and $n = 95$ for the lifetime event description analyses.

The correlation between recent and lifetime autobiographical memory ratings was not significant, Kappa = .15, $p = .133$. We used separate logistic regression models for recent and lifetime autobiographical memory. Both models included the predictors of practice condition, baseline bias (positive vs. negative), and the interaction between these variables to predict the valence (positive vs. negative) of autobiographical memory. For the recent event descriptions, neither the main effect of condition, the main effect of baseline bias, nor the interaction between condition and baseline bias was significant, all ORs < 1, $p > .39$. The main effect of condition had OR = 0.76, 95% CI [0.30, 1.91], and of baseline bias had OR = 0.52, 95% CI [0.11, 2.39]. The interaction between condition and baseline bias had OR = 0.88, 95% CI [0.11, 7.10]. The full model explained 3.5% of variance (Nagelkerke R^2) in the valence of autobiographical recall for recent events, and was not significant, $\chi^2(3, N = 96) = 2.53$, $p = .469$.

For the lifetime event descriptions, none of the effects were significant. The main effect of condition had OR = 0.68, 95% CI [0.27, 1.68], $p = .402$, and of

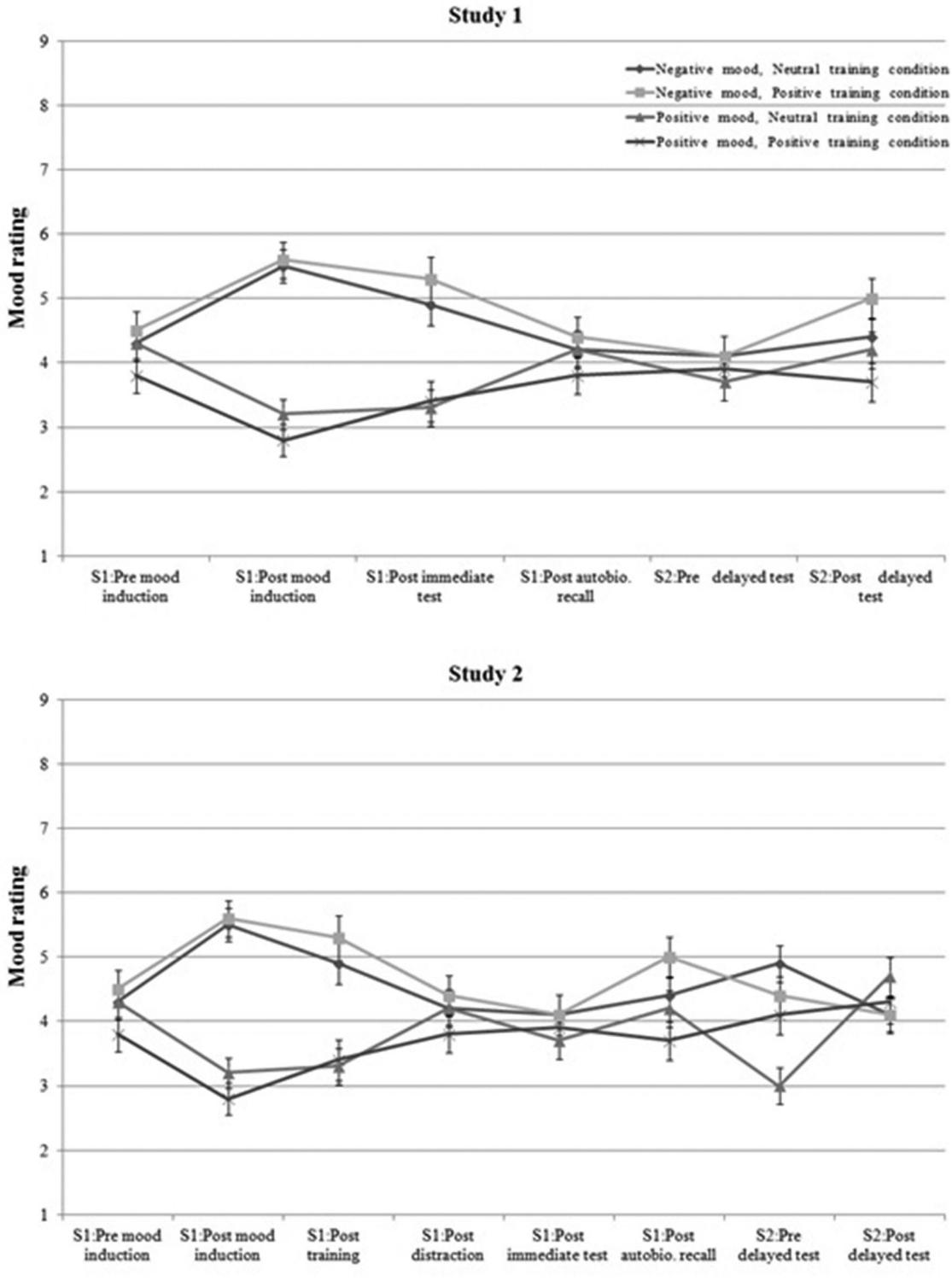

Figure 2. Negative and positive mood ratings throughout the two study sessions, presented separately for Study 1 and Study 2. Error bars represent one SE

Note: S1 refers to Session 1, S2 refers to Session 2.

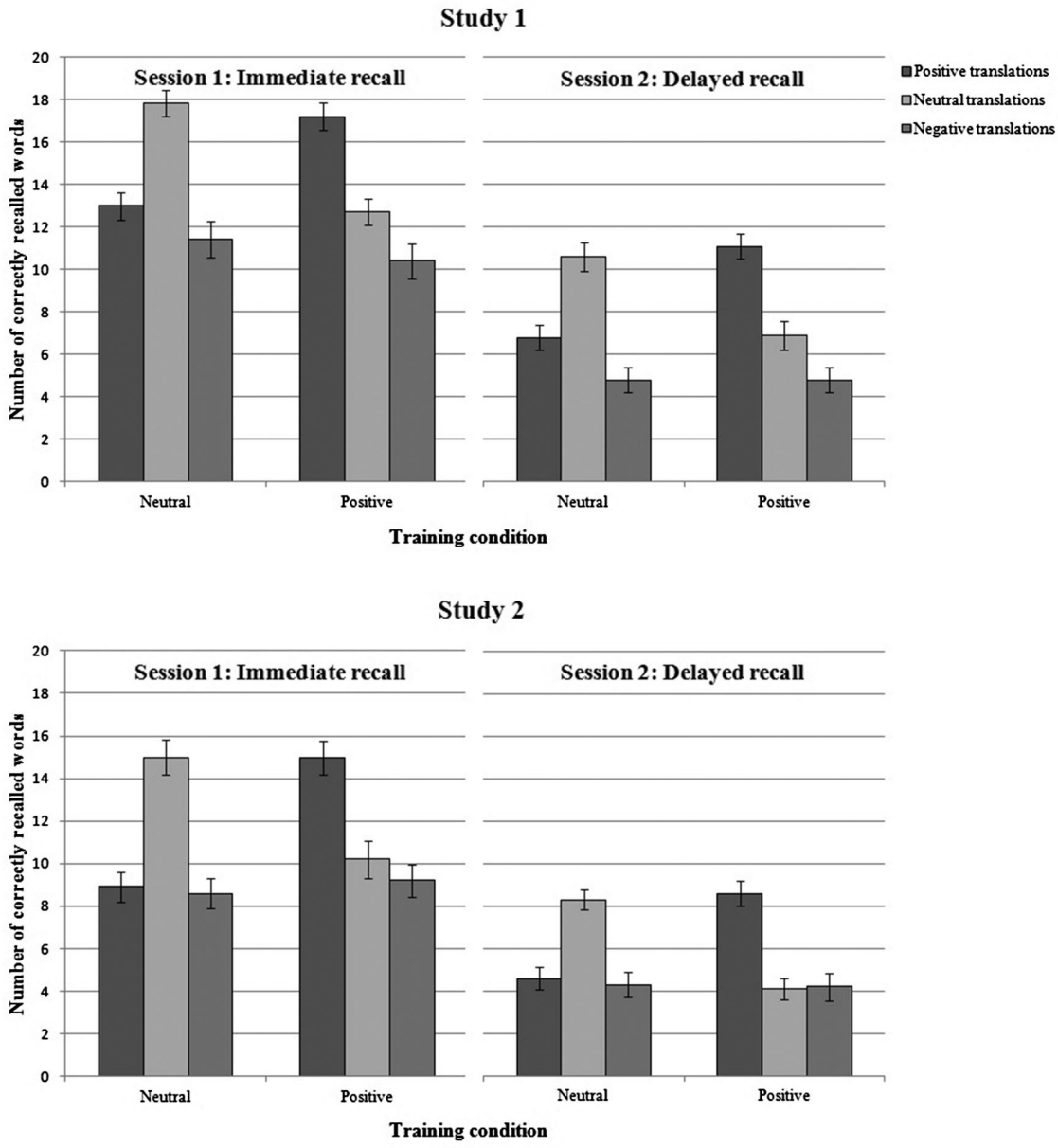

Figure 3. Number of translations recalled on the immediate and the delayed test in Study 1 and Study 2. Error bars represent one SE.

baseline bias had OR = 0.77, 95% CI [0.15, 3.91], p = .752. The interaction between condition and baseline bias had OR = 1.11, 95% CI [0.13, 9.44], p = .927. The full model explained 1.4% of variance (Nagelkerke R^2) in the valence of autobiographical recall for lifetime events and was also not significant, $\chi^2(3, N = 95) = 1.00$, p = .802.

Memory intrusions. The responses to the 15 new Swahili cues are an index of general recall bias in memory intrusions in Session 2. The condition-by-baseline bias-by-valence (positive, neutral, or negative) repeated-measures ANOVA was tested for the number of memory intrusions. None of the comparisons reached significance with all $p > .34$.

Post hoc *Bayesian analyses*

Bayesian analyses were used to further examine the primary outcomes. These analyses suggested the

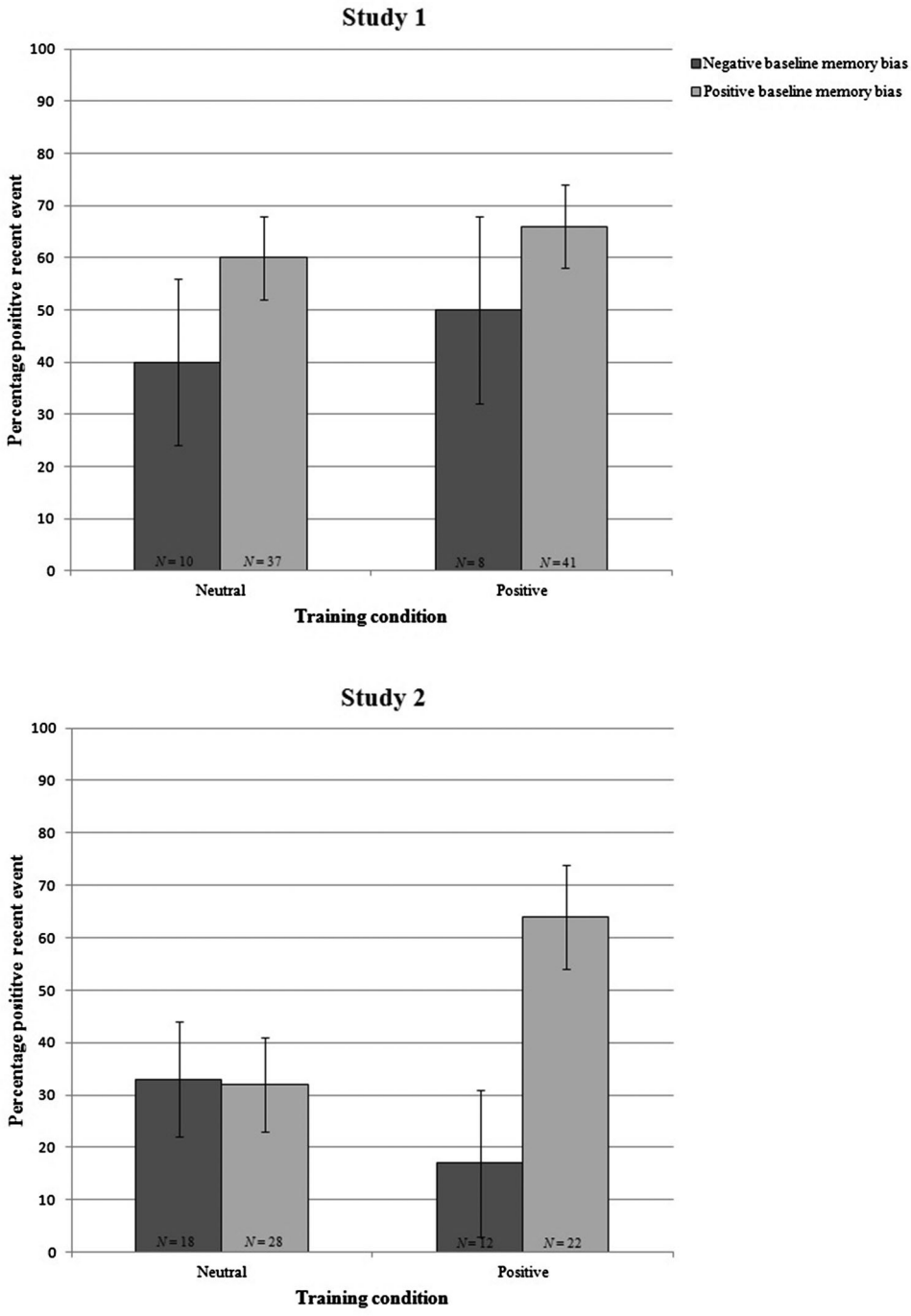

Figure 4. Valence of recent event in autobiographical memory test depending on bias at baseline and condition, presented separately for Study 1 and Study 2. Error bars represent one SE.

evidence of a condition effect on BDI change was inconclusive (condition-by-time BF = 0.57). There was moderate evidence of no condition-by-bias interaction in recent autobiographical recall (BF = 0.10) and of no main effect of condition (BF = 0.13). Similarly, there was moderate evidence of no

condition-by-bias interaction in lifetime autobiographical recall (BF = 0.10), and of no main effect of condition (BF = 0.15).

Discussion

In this study, we applied a novel approach to CBM-Memory by modelling an aspect of ruminative habit – repetitive thinking – in a retrieval-based learning paradigm. By selecting naturally ruminative participants, we examined whether a ruminative bias can be opposed by positive retrieval practice. We indeed found that CBM-Memory resulted in training-congruent retrieval immediately and one week after the training session. However, both neutral and positive training conditions resulted in a decrease in depressive symptoms and rumination and the training did not transfer to a real-world test of memory bias, autobiographical recall. In Study 2, we further examine the relevance of CBM-Memory for clinical practice and attempt to replicate the results of Study 1.

Study 2

Method

Participants

Undergraduate students from the University of Texas at Austin were screened online for depressive symptoms using the BDI-II (Beck et al., 1996) and were invited or participation if their total BDI-II score was ≥ 13 (indicating mild depressive symptom level; Lasa, Ayuso-Mateos, Vázquez-Barquero, Díez-Manrique, & Dowrick, 2000). Due to concern about ethics, students with significant suicidal ideation as reported in item 9 of the BDI-II were not invited to participate. The BDI-II was administered a second time, in the lab, before the start of Session 1 to ensure all participants met severity inclusion criterion (i.e. BDI-II continued to be ≥ 13). See Table 1 for sample characteristics. A total of 100 participants were randomly assigned to either the positive memory training ($n = 46$) or the neutral memory training ($n = 54$). The two groups did not differ in age or gender identification (see Table 1), nor on baseline symptom levels. Participants received course credit for participating.

Materials and procedure

All procedures were approved by the UT Austin IRB. The procedures were the same as in Study 1, with only two differences. First, English rather than Dutch words and measures were used and second, positive and negative mood was also assessed following the training and after the distraction.

Questionnaires, autobiographical recall ratings, and Session 2. After providing informed consent in Session 1, participants completed the questionnaires (MRSI 8-item English version with $\alpha = .72$, BDI-II with $\alpha = .82$, BAI with $\alpha = .85$, RRS 22-item original version with $\alpha = .87$, in that order) via the online REDCap platform (Research Electronic Data Capture; Harris et al., 2009). As in Study 1, both recent and lifetime event descriptions were rated by two independent raters. Kappa > .97, $p < .001$ for both the recent and lifetime event descriptions. To start Session 2, participants received an email with a link to the online follow-up task in REDCap and with a personal code to log in.

Statistical analyses

All analyses followed the same approach as Study 1.

Results

Recall

To examine whether the training indeed created a differential recall of the emotionally valenced words both on the immediate and the delayed test, the number of correctly recalled translations was submitted to a mixed-design ANOVA, with a between-subjects factor for practice condition and within-subject factor for valence (positive, neutral, or negative word meanings). The condition-valence interaction was significant both for the immediate and the delayed test, $F(2,97) = 89.03$, $p < .000$, $\eta_p^2 = .65$ and $F(2,97) = 98.78$, $p < .001$, $\eta_p^2 = .67$, respectively. See Figure 3 for a visual representation of these results. A series of *t*-tests showed that the positive training produced the most correct recall of positive words, and the neutral training condition showed the greatest successful recall of neutral words on both tests, all $p < .001$. There was no significant difference between the conditions on recall of negative words, $p > .60$ on both tests. As expected, the training created differential recall of emotional target words that lasted at least one week. However, positive training did not reduce the number of negative translations recalled, compared to neutral training, as predicted.

A simple order effect driving the recall results could also be ruled out in Study 2, as only 0.3% (4 in total) of answers new Swahili cues in Session 2 were correct

translations of the Swahili words that approach at this position in the list during the learning phase.

Mood induction

As in Study 1, positive and negative mood ratings were separately submitted to a mixed-design ANOVA. The interaction effect of practice condition (positive vs. neutral) by timing of the ratings (pre vs. post mood induction) was not significant for either type of ratings, both Fs < 1.0, $p > .62$, $\eta_p^2 < .01$. Only the main effect of time was significant for both the negative and positive mood ratings, $F(1,98) = 43.74$, $p < .001$, $\eta_p^2 = .31$ and $F(1,98) = 63.14$, $p < .001$, $\eta_p^2 = .39$, respectively. As in Study 1, negative mood increased and positive mood decreased similarly across conditions (see Figure 2).

Transfer effects of the training on depressive symptoms, rumination, and mood

Table 1 reports descriptive statistics for the BDI-II, MRSI, and RRS in both sessions. To assess whether the conditions of retrieval practice yielded differential effects on depressive symptoms and on rumination, the condition-by-time (Session 1 vs. Session 2) interactions in BDI-II scores and RRS total scores were evaluated and found to be statistically nonsignificant; for both, $F < 1.0$, $p > .67$, $\eta_p^2 < .01$. The main effect of time was significant for both the BDI-II and the RRS, $F(1, 98) = 5.01$, $p < .05$, $\eta_p^2 = .05$ and $F(1, 98) = 20.14$, $p < .001$, $\eta_p^2 = .17$, respectively. There was a small but significant decrease in depressive symptoms and in trait rumination from the beginning of Session 1 to Session 2 in both conditions.

The condition-time interaction was not significant for state rumination (measured at the beginning of Session 1, immediately following training, and at the beginning of Session 2), $F < 1.0$, $p = .490$, $\eta_p^2 = .02$. The main effect of time was significant, $F(2, 97) = 70.74$, $p < .001$, $\eta_p^2 = .59$. State rumination increased from the beginning of Session 1 to post-training in both conditions. However, in both conditions state rumination decreased from post-training to Session 2, as well as when comparing the beginning of Session 1 to Session 2; $p < .001$ for all paired sample t-tests.

Mood ratings were submitted to a mixed-design ANOVA, with practice condition as the between-subjects factor and rating valence (positive or negative) and time of measurement as within-subjects factors (post-mood induction, post-training, post-distraction, post-immediate test, post-autobiographical memory test, pre-delayed test, post-delayed test). Figure 2 illustrates the means. The only significant effect was shown by the valence-by-time interaction, $F(6,93) = 18.91$, $p < .001$, $\eta_p^2 = .55$. As in Study 1, positive mood increased and negative mood decreased in both conditions and in both sessions. None of the comparisons between conditions were significant, all $p > .22$.

Transfer of the training effects to other memory processes

Autobiographical recall. As in Study 1, participants who did not recall any of the SRET words correctly were excluded from these analyses ($n = 8$). A total of 57 participants had more positive relative to negative pre-existing bias, and 35 participants had more or equal negative to positive bias.

One participant did not provide a response on the autobiographical memory test. For 8 of the lifetime event descriptions and 12 of the recent event descriptions, the raters could not determine whether the event was positive or negative because the description was non-emotional or unclear. This resulted in a sample of $n = 80$ for the following analyses; the number of participants per subgroup is presented in Figure 4.

The ratings indicated no correlation between recent and lifetime autobiographical memory, Kappa = −.02, $p = .872$. We used separate logistic regression models for recent and lifetime autobiographical memory bias. Both models included the predictors of condition, baseline bias (positive vs. negative), and the interaction between these variables to predict the valence (positive vs. negative) of autobiographical memory. For the recent event descriptions, the condition-baseline bias interaction was significant, OR = 9.24, 95% CI [1.07, 79.78], $p = .043$. In individuals with a pre-existing positive memory bias, the positive training resulted more frequently in recall of a positive event than did the neutral condition, OR = 0.27, 95% CI [0.08, 0.88], $p = .029$. Additionally, across participants in the positive training condition, those with a positive pre-existing bias recalled more positive events, OR = 8.75, 95% CI [1.52, 50.31], $p = .015$. However, the baseline bias groups in the neutral training condition did not differ significantly, OR = 0.95, 95% CI [0.27, 3.34], $p = .933$. Contrary to our hypotheses, the conditions did not differ significantly on autobiographical recall in individuals with a pre-existing negative bias, OR = 2.50, 95% CI [0.41, 15.23], $p = .320$. There was no significant main effect of condition, OR = 0.27, 95% CI [0.08, 0.88], $p = .029$, or baseline bias, OR = 0.11, 95% CI [0.02, 0.66], $p = .015$, on valence of recent

autobiographical memory. The full model explained 14.6% of variance (Nagelkerke R^2) in the valence of autobiographical recall for recent events and was significant, $\chi^2(3, N = 80) = 9.09$, $p = .028$. See Figure 4 for a graphical representation of these results.

For the lifetime event descriptions, none of the effects were significant. There was no significant main effect of condition, OR = 1.32, 95% CI [0.43, 4.11], $p = .628$, or main effect baseline bias, OR = 0.04, 95% CI [0.26, 4.18], $p = .954$, or interaction of condition-baseline bias, OR = 0.68, 95% CI [0.11, 4.34], $p = .684$, on valence of recent autobiographical memory. The full model explained 0.6% of variance in the valence of autobiographical recall for lifetime events (Nagelkerke R^2) and was not significant, $\chi^2(3, N = 84) = 0.40$, $p = .940$.

Memory intrusions. As in Study 1, the condition-by-baseline-bias-by-valence (positive, neutral, or negative) repeated-measures ANOVA was tested for the number of memory intrusions. None of the comparisons reached significance, with all $p > .10$.

Post hoc Bayesian analyses

Bayesian model comparisons were used to further examine the interaction effects in the primary analyses. These analyses provided moderate evidence that there was no difference between conditions in BDI-II change (condition-by-time BF = 0.24). The evidence for a condition-by-bias interaction in recent autobiographical recall was inconclusive (BF = 1.04), but there was moderate evidence that condition did not have a main effect (BF = 0.25). There was moderate evidence of no condition-by-bias interaction in lifetime autobiographical recall (BF = 0.12), and of no main effect of condition (BF = 0.11).

Discussion

The results of Study 2 largely replicate the findings in the high-ruminating sample in Study 1. The training resulted in training-congruent recall, but its effect did not transfer to autobiographical memory bias or to depressive symptoms. However, here we found that in dysphoric individuals with a pre-existing positive bias, the training resulted in more positive autobiographical memory bias after the positive compared to the neutral training condition.

General discussion

These two studies examined whether a single session of positive CBM-Memory led to more positive autobiographical memory bias, or a larger reduction in depressive symptoms and rumination, compared to a neutral CBM-Memory training condition. The studies focused on two independent vulnerable samples: one with high levels of rumination and the other with elevated depressive symptoms (i.e. dysphoric). Consistent with previous studies (Hertel et al., 2017; Vrijsen et al., 2016), the results revealed that the retrieval training resulted in training-congruent recall of emotion information in both samples. However, the positive and the neutral training conditions yielded comparable symptom change, although we expected the positive condition to outperform the neutral condition.

Only one group, dysphoric individuals with positive pre-existing memory bias, showed more positive autobiographical memory bias after the positive compared to the neutral training. That is, for individuals with elevated depressive symptoms who nonetheless showed a positive memory bias pre-training, the positive training resulted in positivity in autobiographical memories. Unfortunately, the positive training did not stimulate positive autobiographical recall in the high-rumination sample, or in individuals with a negative pre-existing memory bias. This suggests that, contrary to previous findings of baseline bias differences in treatment response (e.g. Calamaras et al., 2012), the positive CBM-Memory training did not oppose the pre-existing memory bias. Dysphoric individuals with a negative memory bias and high trait-ruminating individuals may need more help in countering this negative and unhealthy processing style. Future work should aim to examine whether a higher dose (i.e. more sessions) of positive CBM-Memory may yield stronger effects on depressive symptoms and autobiographical memory bias in vulnerable individuals. Also, having participants select self-relevant verbal stimuli and training retrieval for individualised material may results in stronger training effects as bias is especially strong for self-relevant information (see Wisco, 2009). Furthermore, this finding warrants future exploration of CBM-Memory targeted to increase resilience to developing negative biases over time.

The timing of the autobiographical recall test may also help explain the lack of transfer effects in both studies. Autobiographical bias was tested directly after the training in Session 1. If the training affects which new experiences are remembered, the transfer of the training to autobiographical memory bias should be stronger one week later. It may also be

that practicing positive memory in daily life would yield a change in memory processing. Future studies should include a measure of recent autobiographical memory bias at follow-up.

The nonsignificant difference between the two conditions on change in rumination, depressive symptoms, and mood may in part be due to the neutral condition being a "lower-dose" version of the positive training. In the neutral condition, memory is also trained away from the depressotypic negative bias, although in theory less so than in the positive training condition. Hence, the effects of the two conditions on memory bias and depressive symptoms may be rather similar. Important to note here is that the *post hoc* Bayesian analyses confirmed the null-effect of condition on depressive symptoms change in the dysphoric sample, but yielded inconclusive results in the high-ruminating sample. This warrants further examination. Other CBM studies also found the active training and sham/control/placebo training to produce similar effects on depression or anxiety symptoms (but perhaps via different mechanism) (Badura-Brack et al., 2015; Beevers, Clasen, Enock, & Schnyer, 2015; de Voogd et al., 2017). Important to note is that without a no-training condition, we cannot be certain that the current findings are due to the targeted processes of retrieval or whether we find training-nonspecific effects. The previous CBM-Memory studies, however, provide evidence for retrieval being the working mechanism by comparing the training conditions to a no-training condition (Hertel et al., 2017; Vrijsen et al., 2016).

Results revealed that both rumination and dysphoria comprise subgroups with both positive and negative processing styles. More negative (relative to positive) pre-existing bias was more prevalent in the dysphoric sample (where $n = 43$ had a more negative bias) than in the high-ruminating sample ($n = 19$). This indicates that dysphoric individuals may have a stronger negative processing style and that the samples may hence be qualitatively different with regard to depression risk factors. This was also reflected by the differences in baseline depressive symptoms between the samples ($M = 22.3$ in dysphorics versus $M = 11.0$ in ruminators). Although depression and rumination are highly related ($r = 0.58$, $p < .001$ in high-ruminating and $r = .61$, $p < .001$ in dysphoric sample), they represent distinct concepts. The fact that quite similar results were found in both samples indicates that rumination may indeed be the mechanism of change for the CBM-Memory training. It also suggests that recall of emotional information can be trained in vulnerable individuals. However, collectively the results indicate that one session of positive CBM-Memory does not affect autobiographic memory bias in individuals who are considered to be at-risk for depression.

There are several limitations that warrant consideration. We do not know how participants "searched" their memory for word pairs, or which specific memory processes are affected by the training. In fact, even unsuccessful attempts to retrieve a word may facilitate future learning of a word-pair (Grimaldi & Karpicke, 2012), indicating that retrieval of training-congruent words might have been facilitated even when the native word was not recalled at the (first) time of testing. By repeated multi-stimuli presentations, we limited the possible influence of attention bias on the learning and later recall of the stimuli. However, we did not measure attention bias, which still might have influenced learning. Our data collection did not include ratings on the emotional intensity of the lifetime and recent life events, thus limiting our ability to draw conclusions about their salience.

Overall, the current study on CBM-Memory and the ones preceding it (Hertel et al., 2017; Vrijsen et al., 2016) indicate that CBM-Memory results in training-congruent retrieval. However, one session of CBM-Memory does not appear to transfer to autobiographical emotional memory or depressive symptoms. CBM is currently mostly studied as stand-alone treatment. Achieving long-term change in depression vulnerability may entail offering patients CBM-Memory alongside a psychological or pharmacological treatment programme. However, the research does not encourage clinical application at this point, although patients are qualitatively different from vulnerable student samples (with regard to e.g. motivation to change, demographics, life events) and different results may be found. How to make use of the causal link between memory bias and depression to improve treatment of depression requires further research.

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