Are attentional bias and memory bias for negative words causally related?

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Abstract

Background and Objectives: In cognitive theories of depression, processing biases are assumed to be partly responsible for the onset and maintenance of mood disorders. Despite a wealth of studies examining the relation between depression and individual biases (at the level of attention, interpretation, and memory), little is known about relationships between different biases. The purpose of the present study was to assess if attentional bias is causally related to memory bias. **Methods:** 71 participants were randomly assigned to a control ($n = 37$) or attentional training group ($n = 34$). The attentional manipulation was followed by an explicit, intentional memory task during which novel neutral, negative, and positive words were presented. **Results:** It was found that individuals with elevated depression score trained to orient away from negative words did not display a memory bias for negative words (adjectives) whereas similar individuals displayed this memory bias in the control condition. **Limitation:** Generalization of the findings is limited because of the short study time frame and specific nature of the memory task. **Conclusions:** These results indicate that altering attentional bias can influence elaborative processing of emotional material and that this bias could be one of the causes of mood congruent memory in depression.

Keywords: attentional bias, memory bias, anxiety, depression, cognitive bias modification

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Cognitive theories of depression and anxiety postulate that processing biases are vulnerability and maintenance factors for these disorders (Beck, 1976; Clark, Beck, & Alford, 1999; Mathews & MacLeod, 2005; Williams, Watts, MacLeod, & Mathews, 1997). That is, certain types of processing strategies are thought to result in selection and interpretation of endogenous and exogenous sources of information in a way that both reflects and serves to induce, maintain or exaggerate a maladaptive view of self and the world. For both disorders there is extensive research on biased attention, interpretation, and memory. Only recently theorists have begun to consider the question whether these biases are related (Everaert, Koster, & Derakshan, 2012; Hertel, 2002; Hirsch, Clark, & Mathews, 2006). The current paper is aimed to examine the causal relation between attentional bias and memory bias for negative words in the context of depression, as depression is characterized by both types of biases. We will first discuss attentional bias and memory bias to then consider how the relationship between these biases can be studied.

Despite initial debate (Williams et al., 1997), recent research has shown that depression is characterized by an attentional bias for negative, self-relevant information (for reviews, see De Raedt & Koster, 2010; Disner, Beevers, Haigh, & Beck, 2011; Gotlib & Joormann, 2010; Peckham, McHugh, & Otto, 2010). The reason why initial attempts at discovering attentional bias in depression were not successful could be related to the presentation duration of emotional stimuli. Although little is known about the time threshold at which this phenomenon can be reliably observed it should be noted that at present there is hardly any support for the existence of attentional bias effect in depression when presentation times are very short, e.g., subliminal (Koster, De Raedt, Goeleven, Franck, & Crombez, 2005; Mogg, Bradley, & Williams, 1995). Of particular importance in this context are the results of eye-

tracking studies indicating that depression is not associated with mood congruent initial shifts of attention but with longer gaze duration (Caseras, Garner, Bradley, & Mogg, 2007) or difficulty in disengagement from negative stimuli (Sears, Thomas, LeHuquet, & Johnson, 2010). At longer stimulus presentation times attentional bias is usually interpreted as reflecting sustained attention, difficulty in disengagement or other forms of interference occurring at later, more elaborative stages of processing (Gotlib et al., 2004; Koster et al., 2005).

Empirical research has also indicated that depression is associated with memory bias. In an influential narrative review of memory bias in depression Blaney (1986) concluded that mood congruent explicit memory bias is a robust phenomenon only in clinically depressed participants asked to self-referentially encode emotional material. Under such conditions clinical depression is associated with improved recall of negative information. To our knowledge, only one quantitative review of memory bias in depression has been published (Matt, Vázquez, & Campbell, 1992). Their results indicate that sub-clinical depression is associated with lack of positive recall asymmetry: non-depressed individuals recall positive material better than negative material and this effect seems to be absent in the sub-clinically depressed. Since then, memory bias is considered a hallmark feature in cognitive models of depression (Williams et al., 1997).

Despite decades of research on the presence and role of individual biases in depression, there has been very little consideration of influences among different processing biases. This is remarkable since cognitive models of depression propose that cognitive schemas influence processing at the attentional as well as the memory level (Beck, 1976). In the basic experimental literature there is ample evidence that attention influences memory processes (e.g., Cowan, 1995), however this has received little study in the context of emotional

processing biases. Studying the interplay between biases is considered important as – according to the combined bias hypothesis (Everaert et al., 2012; Hirsch et al., 2006) - single biases (for instance at the level of attention) may act as a gateway to influence other levels of information processing (memory and interpretation), which in concert can maintain and exaggerate negative beliefs.

Recently studies have started to consider relations among attention and memory bias. In a seminal study, Gotlib et al. (2004) used emotional face dot-probe, emotional Stroop, and incidental recall tasks with self-referential encoding to investigate correlations between processing biases. No significant correlations were found between attentional and memory bias indices for sad, socially threatening, physically threatening or positive stimuli in participants diagnosed with major depression or social phobia. Alternatively, in a recent study (Koster, De Raedt, Leyman, & De Lissnyder, 2010) dysphoric participants showed an attentional bias for negative words in a spatial cueing task at conditions that allowed elaboration but did not show memory bias in an incidental recall task testing memory for the words presented during the attentional task. However, in this study attentional bias indices correlated with the number of words recalled within *each* emotional valence category (both negative and positive) in the dysphoric group. Moreover, Wells and Beevers (2009) conducted a study presenting happy, sad, angry, and neutral facial expressions for 12 seconds to dysphoric and non-dysphoric individuals. After viewing the faces participants performed a surprise recognition task. Dysphoric individuals showed better recognition accuracy for angry faces and this effect was mediated by average distance between fixations (“breadth of attentional focus” in the authors' terminology), but no differences in fixation durations, number of fixations or memory for sad, happy or neutral faces were observed. Finally, in an eye tracking task depicting slides containing depression-relevant, aversive, neutral, and

positive words, subclinically depressed individuals exhibited an absence of attention bias for positive words, which predicted less accurate recognition of these stimuli (Ellis, Beevers, & Wells, 2011).

It is important to note that the data in the preceding studies cannot determine whether there is a causal relation between attentional and memory bias as the design is correlational in each case. Experimental manipulation of attentional bias would allow to directly examine whether attentional bias influences memory bias. Cognitive Bias Modification (CBM) methodology has been specifically developed to experimentally manipulate information processing bias to investigate its causal effects on symptoms and processes associated with psychopathology (Koster, MacLeod, & Fox, 2009; MacLeod & Mathews, 2012). The typical way to manipulate attention is a modified dot-probe task (MacLeod, Mathews, & Tata, 1986). When used to measure attentional bias it consists of a series of trials during which simultaneously presented emotional and neutral cues are replaced by the probe appearing with equal probability in place of the preceding emotional (congruent trial) or neutral (incongruent trial) stimulus. If the number of congruent trials is much smaller than the number of incongruent trials, directing attention away from emotional or towards neutral stimuli is beneficial to task performance. It has been demonstrated that participants engaging in the training version of the dot-probe task learn to direct their attention in accordance with the imposed contingency (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002).

The purpose of the present study was to assess the causal relation between attentional and memory biases in relation to sub-clinical depression levels by observing the effects of attentional bias training on performance on a subsequent intentional memory task. To the best

of our knowledge this experiment is the first attempt at examining whether attentional training alters the results of an intentional memory test for *novel* emotional information. To this end we allocated individuals to either a condition where attention was trained away from negative words or a non-training control condition and subsequently investigated whether this manipulation influenced explicit memory for novel emotional words. If there is a causal relationship between attention and memory bias, we hypothesized that individuals in the attentional training condition would be worse at recalling negative words. As this study was conducted in non-selected individuals we also examined whether this effect was moderated by depression level.

Method

Overview

An overview of the design is depicted in figure 1. The whole experiment can be divided into an attentional and memory part. Experimental manipulation occurred only in the attentional part, during which participants in the attentional training group completed a modified version of the dot-probe task designed to *reduce* attentional bias to negative words. Verbal stimuli were used both in the attentional and the memory tasks because a recent meta-analysis (Hakamata et al., 2010) indicates that attentional training is more effective with verbal than pictorial stimuli. An explicit memory task was used, as it was found in the pilot study that repeated exposure to emotional words in the dot-probe task resulted in a large number of intrusions when recall was incidental

Participants characteristics

Participants were 71 undergraduate Jagiellonian University students (57 female and 14 male, mean age = 22, $sd = 2.5$) who completed the study in exchange for course credit. They were assigned either to the attentional training ($n = 34$) or to the control condition ($n = 37$).

Assignment to groups was random and the experimenter was blind to condition. Conditions differed only in the assignment to a training or a control version of the dot-probe task.

Materials

Questionnaires. To measure depression the Beck Depression Inventory I (Beck, Steer, & Garbin, 1988) was used. The BDI I is a self-report inventory consisting of 21 items rated on a 4 point scale assessing depressive symptoms during the past week. This questionnaire has good reliability and validity in both healthy and subclinical samples. The internal consistency was .72 in this study.

Stimuli. The list of words used in the dot-probe task comprised 55 adjectives and 36 nouns which were used to create 91 negative-neutral pairs. A separate set of 24 words, 4 in each valence $\times$ word type category (neutral, negative and positive adjectives and nouns) was chosen for the memory task. Negative words in both tasks were associated with lowered mood and self-esteem (e.g., sad, useless), guilt (e.g., guilty, punishment), loss (e.g., mourning), failure (e.g., hopeless), etc. Among these, negative adjectives denoted mostly competence and some morality related traits. These words were taken from a larger set of affective Polish words. The initial list was rated on a 5 point scale (very negative, negative, neutral, positive, very positive) by 6 judges, who were researchers in the field or clinical psychologists. Only words that were consistently categorized as negative (only very negative or negative ratings), positive (only very positive or positive ratings) or neutral (neutral median rating) were included in the final set. All the words were matched for frequency and length within each negative-neutral pair (the dot-probe task) or negative-neutral-positive triple (the memory task).

Current mood measurement. To assess current mood, an analogue mood scale was delivered on the computer screen. The scale consisted of a horizontal line segment with left

end, center, and right end labeled as negative, neutral, and positive, respectively. Participants were instructed to point the mouse cursor at the position which best described their current mood and press the button. The results of current mood measurement were stored as floating point numbers in the -1 (negative) to 1 (positive) range.

The dot-probe task. The dot-probe task consisted of 320 trials. The beginning of each trial was signalled by a white cross presented centrally for 500 ms. This fixation point was replaced by a 1000 ms presentation of neutral and negative words placed one at an upper location and the other at a lower location at a similar distance from the screen center. Following termination of the display of words, a white line segment (slash or backslash) appeared either at the neutral (incongruent) or negative (congruent) word position. Participants were instructed to detect as quickly and accurately as possible the direction of the line by pressing one of the arrow keys. The letters were 1.17 cm high (1° visual angle) and were separated by 4.91 cm vertical distance (4.2°). The line segment was a diagonal of a 0.58 cm high and 0.23 cm wide ($.6^\circ \times .2^\circ$) rectangle. Word pairs were randomized for each participant in such a way that a given pair could be repeated only after the whole set was presented (random selection without replacement). There were 91 word pairs in the dot-probe task and on average each pair was repeated 3.5 times. The direction of the line segment and position (top or bottom) of the negative word was randomized for each participant.

In the training group the probe appeared in the congruent position in 10% of the trials. In the control group the probe appeared with equal probability in the congruent and incongruent position. Since there was only one training session and so a significant number of trials with .5 probability of congruent probe position in the posttest phase could weaken the effects of training, the decision was made not to include separate pretest or posttest phases. Instead, as was done by for example by MacLeod et al. (2002), occasional (.1 probability)

randomly intermixed congruent trials in the attentional training group were introduced, allowing to observe trial-by-trial dynamics of gradual bias change without interfering with training effects.

Filler task. A filler task was presented between the dot probe and the memory task to avoid priming effects. Each trial of the filler task began with a 1000 ms waiting period, followed by a 500 ms presentation of a white cross that served as a fixation point. The fixation point was immediately replaced by a randomly chosen word (either “RIGHT” or “LEFT”) presented in the center of the computer screen. Participants were instructed to press the arrow keys in response to direction named by the words. The filler task was stopped as soon as 5 minutes had passed.

Explicit memory task. The explicit memory task consisted of 24 trials. Each trial began with the presentation of a 500 ms fixation point, after which one of the words chosen randomly from the memory set was shown for 7 sec. We ensured that 8 words of each valence (negative, positive, neutral) were presented. Participants were instructed to try to memorize the words and at the same time rate them on valence using the mouse pointer. Beneath each centrally presented word there was an analogue scale similar to the one used to measure current mood with extreme points labelled as negative and positive and the middle point labelled as neutral.

Procedure. Separate groups of about 5 participants were examined in a sound attenuated laboratory on four consecutive days. They were told that the purpose of the study was to examine the relationship between mood, attention, and memory. After being seated in front of a computer screen at a distance of approximately 67 cm participants filled out a written informed consent form and the BDI. Then, instructions were shown on the computer screen and participants engaged in short practice sessions for the dot-probe and the distracting

task. The beginning of each task in the test phase was self-paced and signalled by a message shown on the computer screen. The attentional part began with current mood measurement, followed by 320 trials of the dot-probe task after which current mood was measured again. Next, in the memory part participants performed 24 trials of the intentional memory task. This was followed by the filler task which lasted 5 minutes. Immediately after that participants were asked to write down as many words from the memory task as possible, without any time limit imposed. At the end of the session participants were asked to guess the purpose of the procedure. No one correctly guessed the exact purpose or hypotheses, although many participants expressed the belief that emotional valence of the words played a role in the experiment. A full debriefing was then provided. Each experimental session took approximately one hour to complete.

(Figure 1 about here)

Results

Data analytic plan

After inspecting differences between the attention training and control groups at pretesting, dot-probe latencies were compared between attentional training and control groups to test if the training was effective. Memory data analyses were supplemented with model comparisons aimed at controlling for response bias. Since the pattern of self-reference effects in memory is different for trait adjectives and nouns (Symons & Johnson, 1997), these two types of words were treated separately. The data were analyzed using R statistical environment (R Development Core Team, 2011). Generalized linear (logistic) mixed models¹ were fitted using glmer procedure in the lme4 package (Bates & Sarkar, 2011).

Inter group differences at pretesting. Participant characteristics are presented in Table 1.

There were no significant differences in age, gender ratio, and depression scores between the

two groups.

(Table 1 about here)

Current mood. Repeated measures ANOVA of current mood data with time (before or after the dot-probe task), gender, and group as independent variables revealed only a marginally significant main effect of time, ($F(1,66) = 20.51, p = .08$), with improved mood after the dot probe task. Importantly, there were no significant differences between the attentional training and control groups in current mood ($F(1,66) = 2.34, p = .13$).

Attentional bias effects

There were 1% error responses on average in the dot-probe task and none of the participants had an error rate exceeding 5%. Reaction times for these trials were removed. In order to ensure that outlying observations had a negligible impact on the results we used median RTs. To ensure that the dot-probe task version used in our study provided a sensitive measure of attentional bias, attentional bias index was regressed on BDI score in the control group. This index was calculated separately for nouns and adjectives by subtracting median congruent correct reaction time from median incongruent correct reaction time. Positive values indicate faster responding to congruent probes.

Attentional bias in the control group. Pearson product-moment correlation between adjective and noun based bias indices in the control group was small and not significant ($r = -.2, p = .2$) implying that both bias indices should be treated separately. BDI scores correlated significantly with noun based attentional bias index ($r = .36, p = .03$), showing that participants who scored higher in the BDI tended to direct their attention towards negative nouns. No statistically significant effects were found for adjective based bias index.

Attentional training effects. To measure attentional training effects a similar bias index was

calculated in the experimental group for early (1-107), middle (108-214) and late (215-320) trials. In this case it was impossible to estimate attentional bias separately for nouns and adjectives because there were only 10% incongruent trials in the training group. Preliminary inspection of bias indices averaged over participants indicated that the change occurred in the late (215-320) trials. Summary statistics for reaction time data from the dot-probe task are provided in Table 2 below.

(Table 2 about here)

Bias index value for early trials was subtracted from bias index value for late trials to obtain an estimate of attentional bias change. Observed change in bias index value between early and late trials in the training group was significant according to the one-sided t-test ($t(33) = 1.9, p = .03$). Bias change effect computed in the same way in the control group was not significant ($t(36) = 1.3, p = .2$).

Memory bias

Recalled words were classified as correct or incorrect recollections (i.e., intrusions) allowing for occasional spelling mistakes. Recalled adjectives and nouns were analyzed separately. Following Baayen, Davidson and Bates' (2008) guidelines mixed (multilevel) logistic regression was used with BDI scores, valence, group and all the possible interaction terms as fixed effects and both subject and item specific random intercept terms. Regardless of the type of analysis no significant effects were found for recalled nouns. Table 3 provides a summary of proportion of items correctly recalled within each group $\times$ type $\times$ valence category.

(Table 3 about here)

Response bias. In order to test for response bias, the final memory data model was compared with an analogous model that also included proportion of intrusions. Intrusions are occasions

where participants report a word in the memory test that has not been presented. As signal detection analysis is not suitable for recall data, analyses of intrusions are informative with regard to response bias. Introduction of this covariate did not improve the fit significantly ($\chi^2(6) = 1.97, p = .92$) showing no evidence that the results could be attributed to response bias. We also tested for the difference in the number of intrusions reported. The groups did not differ with respect to the number of intrusions ($t(74) = 0.89, p = .36$) or the proportion of intrusions ($t(74) = 1.73, p = .19$). However, the number of intrusions was still quite high for some participants. That is why all the memory data analyses except for those related to response bias specifically were performed after excluding 16 participants for whom the number of intrusions was equal to or greater than the number of correct recollections, trading statistical power for validity. This way one can assume that for the remaining data the items reported were more likely to be actually recalled rather than guessed.

Effects of attentional training on memory. To make regression coefficients easily interpretable in terms of the posed questions, nested (separate slopes) parametrization was used and BDI scores were centered on the lowest sample values. The fitted model is summarized in Table 4. Valence effects (the second and third fixed effects coefficients in Table 4) express the differences in recall probability for negative vs neutral and positive vs neutral words for participants with the lowest BDI scores in the control group. The slopes express mood related differences in recall probability *within* each valence $\times$ group category. (Table 4 about here)

As can be seen BDI scores were positively and significantly related to recall probability but only for negative adjectives and only in the control group ($z = 2.12, p = .03$). This effect was not significant and close to zero in the training group. Planned comparisons revealed that inter-group differences between slopes for negative words were significant at

the $p = .03$ level according to the one-sided t -test. This shows that as a result of the experimental manipulation, the high BDI scorers differed in negative adjectives recollection probability. Agreement between model predictions and data on the probability scale for negative adjectives is depicted in fig. 2.

(Figure 2 about here)

Discussion

In cognitive views on depression, several authors (e.g., Beck, 1976; Weems & Watts, 2005) suggested that attentional, memory, and interpretive biases might work together to maintain or even exacerbate specific emotional conditions. Yet, this idea has not been thoroughly investigated (for a review, see Everaert et al., 2012). That is, in some studies where associations between different biases were explicitly addressed, correlations were not found (e.g., Gotlib et al., 2004; Watts & Weems, 2006). Moreover, observational studies are insufficient to establish the causal link between attention, memory, and interpretive bias. Following up on studies showing a correlation between attention and memory bias (e.g., Koster et al., 2010), the current study aimed to directly examine the causal relation between attentional and memory bias. Results show that attentional training away from threat reduced memory bias for negative words in individuals with elevated depression scores. This result is discussed below.

The current study is the first to observe that a brief attention training away from emotional material can influence the way untrained emotional material is memorized. Given that this study was conducted in non-selected individuals it is not surprising that these effects were more pronounced in individuals with elevated depression levels. These individuals are more prone to memory bias for negative words, hence there is more room for an attentional training to have an impact on this memory process. Given the nature of the explicit memory

task it is not possible to be specific on the operational mechanism that is responsible for the attentional influence on memory bias. It could be that the attentional training influenced the amount of negative information that was encoded in the learning phase or that it influenced the way (e.g., self-referential processing) it was encoded. Alternatively, it is also possible that attentional training mainly influenced the recollection of negative words. The current study sets the stage for more fine-grained investigation of the influence between attention and memory.

There are a number of interesting theoretical as well as clinical implications related to the current results. At the theoretical level, the results provide empirical support for some of the predictions of the combined bias hypothesis that states that there is an interplay between biases at the level of attention, memory, and interpretation. (Hirsch et al., 2006; Everaert et al., 2012). In individuals with elevated depression scores attentional bias, which is often seen at the level of attentional disengagement from negative material, can play an important role in enhancing memory for negative information. This selective encoding of information may maintain and exacerbate maladaptive beliefs. At a broader level, the present study shows the potential of investigating causal links between information processing biases using cognitive bias modification. At the clinical level it is important that retraining of attention elicits effects that generalize beyond the attentional processing of information, influencing also memory bias, with the latter bias being considered a hallmark feature of depression (Matt et al., 1992). So far, attentional retraining in depression has yielded mixed results (Baert, De Raedt, Schacht, & Koster, 2010; Wells & Beevers, 2009). The current results suggest that this training could lead to improvement through attentional as well as memory processes.

Several limitations of the present study should be mentioned. First, the present study only comprised a short training in a non-clinical sample so it would be important to examine

whether the training generalizes over time and can also be applied successfully in clinically depressed individuals. Second, we did not use a separate attentional and memory pretest and posttest phases. We chose not to do these in order not to “undo” any attentional training effects and not to provide too much practice on the memory task. Consequently, we were not able to examine within-group changes in memory bias and we could not test mediational hypotheses by examining whether the magnitude of attentional change was associated with memory performance. Given the promising results of the current study, future studies are required to further confirm these findings using more extensive training as well as pre and post-measurement of attentional and memory bias. Third, the calculation of attentional bias scores was based on a discrepant number of responses on congruent versus incongruent trials, which may have lowered the reliability of this index score.

The fact that in the control group the attentional bias was found only for nouns but the memory bias was found for adjectives seems puzzling. Perhaps adjectives, being processed differently than nouns and being more likely to be processed self-referentially (see for example Symons and Johnson, 1997) might require additional processing stages (e.g., self-reference) or, in general, they might require different processing stages than nouns in order to elicit attentional shifts in depressives. This would imply that the attentional bias effect for adjectives might appear when different (perhaps longer?) stimulus presentation times are used.

Finally, the effects of attentional training were only found on explicit memory for adjectives. This pattern could be partially explained in terms of self-reference effects: depression is by definition associated with higher endorsement of negative self-descriptions and adjectives are more likely than nouns to be self-referentially processed. Still, because attentional bias effects were observed only for nouns this finding was somewhat surprising

and the distinction between cognitive biases for adjectives and nouns deserves further investigation given the current findings.

In sum, the current study is among the first to show a causal link between attentional bias and memory bias in individuals with elevated depression scores. It seems possible to weaken the tendency characteristic of these individuals to better remember negative self-referential information by training attention away from negative stimuli. Since there are both theoretical and empirical reasons to believe that attentional and memory biases are vulnerability and maintenance factors for emotional disorders the current use of cognitive bias modification procedures could be a fruitful way to examine causal relations between vulnerability factors.

Footnotes

¹ In contrast to many studies using repeated measures ANOVA, a mixed logistic regression approach is more suitable to examine such accuracy data. That is, all the essential assumptions for an ANOVA approach are strongly violated by this kind of data which is not the case for the mixed logistic regression approach.

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Table 1.

Participant Characteristics.

	Condition			
	Control	Training		
	<i>M</i> (SD)	<i>M</i> (SD)	<i>t</i> (1,69)	<i>p</i>
BDI	7.70 (6.08)	10.24 (6.08)	1.9	.06
Age	22.11 (3.07)	21.53 (1.73)	1.0	.3
Gender (f/m)	29/8	28/6	$\chi^2=0.01$	.9

Table 2.

Reaction time data in the dot-probe task.

	Trials		
	Early	Middle	Late
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
<i>Control group</i>			
Incongruent	622 (105)	610 (109)	598 (113)
Congruent	620 (105)	611 (109)	603 (112)
<i>Attentional training group</i>			
Incongruent	609 (92)	588 (74)	577 (87)
Congruent	596 (83)	583 (67)	584 (92)

Table 3.

Proportion of items correctly recalled in the memory task.

	Adjectives		Nouns	
	Control	Training	Control	Training
Neutral	0.13	0.12	0.40	0.35
Negative	0.15	0.11	0.54	0.42
Positive	0.18	0.23	0.40	0.52

Table 4.

Summary statistics of binomial generalized linear mixed effects model for memory data

Coefficient	Estimate	Std. Error	<i>z</i>	<i>p</i>
Intercept				
(Neutral/Control group/BDI=low)	-2.03	0.61	-3.31	0.001
Negative	-1.08	0.89	-1.22	0.221
Positive	0.24	0.78	0.31	0.759
Training group	-0.34	0.78	-0.44	0.663
Negative:Training group	1.05	1.06	0.99	0.322
Positive:Training group	1.00	0.92	1.09	0.277
<i>Separate BDI slopes in the control group</i>				
Neutral	-0.02	0.06	-0.31	0.755
Negative	0.13	0.06	2.12	0.034

Positive	0.00	0.,06	0.08	0.934
<i>Separate BDI slopes in the training group</i>				
Neutral	0.02	0.05	0.44	0.662
Negative	-0.02	0.05	-0.45	0.655
Positive	-0.03	0.04	-0.77	0.439
<i>Random effect</i>	<i>Variance</i>			
Subject	0.40			
Word	0.71

Figure 1. Overview of the experimental procedure

Figure 2. Negative adjectives recall probability as a function of BDI score. Lines represent fitted model predictions based on fixed effects only and points represent aggregated (binned) accuracy data for ten equal size groups in attentional training and control

conditions. BDI is positively associated with negative adjectives recall probability in the control group only.