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Attention, Interpretation, and Memory Biases in Subclinical Depression: A Proof-of-Principle Test of The Combined Cognitive Biases Hypothesis

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Abstract

Emotional biases in attention, interpretation, and memory are viewed as important cognitive processes underlying symptoms of depression. To date, there is a limited understanding of the interplay among these processing biases. This study tested the dependence of memory on depression-related biases in attention and interpretation. Subclinically depressed and non-depressed participants completed a computerized version of the scrambled sentences test (measuring interpretation bias) while their eye movements were recorded (measuring attention bias). This task was followed by an incidental free recall test of previously constructed interpretations (measuring memory bias). Path analysis revealed a good fit for the model in which selective orienting of attention was associated with interpretation bias, which in turn was associated with a congruent bias in memory. Also, a good fit was observed for a path model in which biases in the maintenance of attention and interpretation were associated with memory bias. Both path models attained a superior fit compared to path models without the theorized functional relations among processing biases. These findings enhance understanding of how mechanisms of attention and interpretation regulate what is remembered. As such, they offer support for the combined cognitive biases hypothesis or the notion that emotionally biased cognitive processes are not isolated mechanisms but instead influence each other. Implications for theoretical models and emotion regulation across the spectrum of depressive symptoms are discussed.

Keywords: depression, combined cognitive biases, attention, interpretation, memory.

Attention, Interpretation, and Memory Biases in Subclinical Depression: A Proof-of-Principle Test of The Combined Cognitive Biases Hypothesis

Attention, interpretation, and memory are regarded as critical cognitive processes involved in the onset, maintenance, and recurrence of depressive symptoms such as sustained negative affect, rumination, and emotion dysregulation. At-risk (e.g., subclinically or remitted depressed) as well as clinically depressed individuals exhibit difficulties when disengaging attention from negative information, do not show the typical attention bias for positive information experienced by non-depressed individuals (De Raedt & Koster, 2010; Peckham, McHugh, & Otto, 2010), tend to interpret ambiguous information as negative (Wisco, 2009), and recall unduly negative memories (Matt, Vazquez, & Campbell, 1992). Although considerable research has been successful in demonstrating emotional processing biases in various depressed samples, most studies investigated these biases as separate, independent phenomena. While this approach improves insight in how a specific bias affects behavior, it is also limited in that it does not show how these biased cognitive processes interact, which is a prerequisite for profound insight in each individual cognitive bias as well as emotionally distorted cognitive functioning as a whole. Acknowledging this limitation, a consensus is growing among theorists that cognitive biases should be studied in an integrative manner (e.g., Everaert, Koster, & Derakshan, 2012; Hertel & Brozovich, 2010; Hirsch, Clark, & Mathews, 2006).

Interrelations among cognitive biases have been considered since the earliest theoretical frameworks of emotional processing in depression (e.g., Clark, Beck, & Alford, 1999; Ingram, 1984; Williams, Watts, MacLeod, & Mathews, 1988, 1997). A central tenet within these frameworks is the notion that emotional biases in attention, interpretation, and memory do not operate as isolated processes, but are interdependent and that such interactions between biases have a greater impact on the course of depression than if these biases would operate in isolation (i.e., the combined cognitive biases hypothesis; Hirsch et al., 2006). Providing empirical evidence for this hypothesis, the accumulated experimental data from non-disordered samples indicates that attention and memory processes are closely interlinked (e.g., Chun & Turk-Browne, 2007; Shafer & Dolcos, 2012). However, in research on depression, interrelations among emotional biases in attention, interpretation, and memory have received limited investigation.

Empirical Findings in Depression

Attention and Memory Biases

An influential study in clinically depressed patients examined associations between selective attention and memory bias using a dot probe task with emotional faces (measuring attention bias) and an incidental free recall test of previously encoded words (measuring memory bias)(Gotlib et al., 2004). The authors indeed observed negative biases in both attention and memory; however, there were no significant correlations between the cognitive bias indices. These data suggest that clinical depression is characterized by attention and memory biases, but also that these biases are independent. Note, however, that this study focused on correlations between biased cognitive processes using unrelated tasks and different stimulus materials, without examining the dependence between biases in attention and memory. As such, it provides a limited test of the combined cognitive biases hypothesis.

This limitation has been addressed in research on subclinical depression by using similar stimulus materials across multiple cognitive tasks. A first study demonstrated that, under task conditions that allowed elaboration in a spatial cueing task, negative biases in attention predicted later recall of negative stimuli that were presented during the preceding attention task (Koster, De Raedt, Leyman, & De Lissnyder, 2010). More evidence comes from a study in which nondepressed and subclinically depressed individuals first viewed slides depicting depression-relevant, aversive, neutral, and positive words while their gaze behavior was recorded. This naturalistic scanning task was followed by an incidental recognition test of the previously presented words. Results showed that the absence of attention bias for positive words, typical for subclinically depressed individuals, was associated with less accurate recognition of these stimuli (Ellis, Beevers, & Wells, 2011). The observations from this cross-sectional research are further substantiated by a recent investigation in which non-selected individuals were trained through experimental procedures to attend away from negative words to examine the causal influence of attention bias on memory (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013). Consistent with prior findings, it was observed that individuals with higher symptom levels did not display a memory bias for negative words when they were trained to orient attention away from negative words, whereas a typical memory bias occurred in the no-training control group.

Taken together, findings from research examining the interplay between attention and memory biases at subclinical depressive symptom levels are in contrast to initial findings in clinical depression. Research on subclinical depression suggests that emotional biases in memory can be explained by emotional biases in attention during prior presentation of emotional information.

Interpretation and Memory Biases

Memory bias has also been studied in relation to interpretation. A study by Hertel and El-Messidi (2006) examined associations between interpretation and memory processes under conditions of heightened self-focused attention. The data revealed that subclinically depressed individuals made more personal interpretations of critical homographs (e.g., loaf, reflect) and recalled these personally interpreted homographs better under conditions of experimentally heightened self focus. Importantly, this memory bias was observed only to the extent that prior interpretations were taken into account. Moreover, two cognitive training studies in nonclinical samples experimentally induced either a positive or a negative interpretation bias to examine the effects on memory. A study by Salemink, Hertel, and Mackintosh (2010) observed training-congruent effects on recall of endings of ambiguous scenarios that were presented before the interpretation bias training. That is, participants trained to interpret ambiguous information as negative recalled more negative endings of ambiguous scenarios reflecting their own interpretations prior to the training, and vice versa for positive information. These findings were extended by the observation that induced interpretation biases can also affect memory for subsequently encountered ambiguous scenarios in a bias-congruent manner (Tran, Hertel, & Joormann, 2011). In sum, current research on links between interpretation and memory indicates that tendencies to interpret ambiguous information in a biased manner are critical to understanding emotional biases in memory.

Limitations of Prior Research

Despite the emerging research germane to the combined cognitive biases hypothesis, several caveats in this research area limit the understanding of the functional relations among attention, interpretation, and memory biases. Besides the paucity of studies and their methodological constraints (for a review, see Everaert et al., 2012), more importantly, we still lack a comprehensive insight into the (time)course of processing biases. That is, it remains untested how attention is deployed *while* emotional information is interpreted and how this sets the stage for emotional biases in memory. Note, in this regard, that attention is not a unitary mechanism (e.g., Chun, Golomb, & Turk-Browne, 2011) and, therefore, emotional biases in distinct components of attention (e.g., selection, maintenance processes) might relate differently to biases at later processing stages (i.e., interpretation, recall). On the one hand, attention mechanisms that determine which information is processed (i.e., selection mechanism of attention) might be strongly related to subsequent interpretation of this information and only weakly to memory for the encoded information. This is because selection alone might not determine how well information is processed (but only what) and, therefore, it does not necessarily lead to better memory. In line with this idea, some cognitive models of depression propose that emotional biases in attention influence how occurring events are interpreted through selection of competing information for further interpretation which in turn determines what will be remembered (Joormann, Yoon, & Zetsche, 2007; Williams et al., 1988). In other words, these models predict that selection mechanisms of attention regulate memory via their impact on interpretation processes. On the other hand, attention processes that are involved in how extensively target information is processed (i.e., maintenance of attention) might be strongly related to the extent to which this information is remembered. Similarly, some cognitive models of depression emphasize the importance of biased maintenance of attention during elaboration on emotional information in enhancing memory for negative material (Ingram, 1984; Williams et al., 1997). To explain memory biases, these models attribute a critical role to attention biases at the later or elaboration processing stages, with attention affecting the processing of emotional information in the absence of overt competition and not at the selection of competing information.

Thus, it is clear that several cognitive frameworks of depression make different, seemingly competing, predictions on the complex interplay among attention, interpretation, and memory biases. Selection and maintenance of attention are hypothesized to account for memory of emotional information via different pathways. To advance insight into the functional relations among these emotionally biased cognitive processes, we set out to investigate these processes in a single study.

The Present Study

This study was designed as a proof-of-principle test of the *combined cognitive biases hypothesis* with respect to the dependence of memory on emotional biases in both attention and interpretation. Following different predictions by cognitive models (e.g., Clark et al., 1999; Ingram, 1984; Joormann et al., 2007; Williams et al., 1988, 1997), we modeled functional relations among distinct mechanisms of attention, interpretation, and memory biases through path analysis. This powerful data-analytic technique allows a comprehensive test of sets of a priori hypothesized pathways between multiple variables. We built a first path model (Model 1) in which a bias in the selection mechanism of attention is associated with interpretation bias, which is in turn associated with memory bias. In addition, we added links between depression levels and each processing bias to the model to account for depressive symptom levels in explaining the associations among biases. Moreover, in a second path model (Model 2), depression levels are related to negative biases in maintenance and elaboration processes which are in turn related to a congruent bias in memory. To test the notion that emotionally biased cognitive processes influence each other rather than operate as isolated mechanisms, Model 1 and 2 were contrasted with a path model in which attention, interpretation, and memory biases are individually tied to depressive symptom levels without any relations modeled among emotionally biased cognitive processes (Model 0).

In this study, we measured emotional biases at multiple stages using a sequence of related cognitive tasks. We assessed online attention for emotional information using eye movement registration *while* subclinically depressed and non-depressed participants performed an interpretation task. Next, we tested explicit memory for the interpretations. An asset of this study design is that the task conditions allow the investigation of the online interplay among emotionally biased cognitive processes in a highly controlled, though ecologically-valid, experimental setting. That is, individuals *actively* select competing positive and negative information, elaborate on the target item relevant to the active process of making meaning and, by necessity, they focus attention on this information. By subsequently testing memory for the constructed meanings, the paradigm enables a stringent investigation of whether emotional biases in mechanisms of attention and interpretation are reflected in memory for the encountered emotional information.

Method

Participants

Seventy-one undergraduate students (62 women and 9 men; age range: 17-33; mean age 20.31 years) were recruited for this study. Recruitment was based on Beck Depression Inventory – II (BDI-II; Beck, Steer, & Brown, 1996; Dutch version: Van der Does, 2002) scores obtained in a prescreening resulting in a broad range of BDI-II scores at the moment of participation (see below). Six participants reported use of antidepressant medication. All participants were native Dutch speakers with normal or corrected-to-normal vision. They received either course credits or 10 euro in exchange for their participation.

Depressive Symptom Severity

The BDI-II measured severity of depressive symptoms with 21 items rated on a scale from 0 to 3. This self-report measure has good reliability and validity in both healthy and depressed samples (Beck et al., 1996; Van der Does, 2002). The internal consistency was α=.92 in this study. At testing, BDI-II scores ranged from 0 to 40, with 39 individuals reporting minimal (BDI-II cut off range: 0-13), 12 mild (BDI-II cut off range: 14–19), 15 moderate (BDI-II cut off range: 20-28), and 5 severe symptom levels (BDI-II cut off range: 29-63). A mean score of 13.56 (*SD*=9.57) was observed in this sample.

Stimulus Materials

A set of 105 Dutch scrambled sentences (60 emotional, 45 neutral sentences) was used as stimuli. Emotional scrambled sentences retrieved from Van der Does (2005) were modified to control for psycholinguistic variables that are known to strongly influence eye movements (Rayner, 1998). Each emotional scrambled sentence presents one positive and one negative target word (e.g., “winner” and “loser” in “am winner born loser a I”), that were matched between valence categories on word length, word class, and CELEX-based word frequency using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004). Paired samples *t*-tests showed no significant differences between negative and positive target words on these lexical variables (all *p*'s>.05)[1]. Word position within each scrambled sentence was randomized with the constraint that emotional words neither occurred next to each other, nor as the first or last word within a scrambled sentence. These restrictions were enforced to control for parafoveal processing of adjoining words (Schotter, Angele, & Rayner, 2012) and wrap-up effects (Rayner, Kambe, & Duffy, 2000) which might influence fixations on emotional target words. Moreover, we insured that the positive word was presented before the negative word in exactly half of the emotional scrambled sentences, and vice versa. Moreover, word order criteria imposed on the emotional scrambled sentences were also applied to neutral target words (e.g., "cinema" and "theatre" in "the I theatre visit cinema often") in the neutral scrambled sentences. All scrambled sentences were self-referent and six words long.

Assessment of Cognitive Biases

Attention bias. Emotional biases in attention were measured through eye movement registration during *stimulus display trial parts* of the interpretation task (see below). This methodology enables online measurement of visual attention and provides multiple valid and sensitive parameters to index this complex cognitive process within the current experimental task (reading) setting (Rayner, 1998). For this study, the total fixation frequency (i.e., total number of fixations) and total fixation duration (i.e., summation of the duration across fixations) on the target words in the scrambled sentences (i.e., the areas of interest) served as the key dependent variables. These parameters are commonly reported indices of attention bias sensitive to individual differences related to depression (e.g., Kellough, Beevers, Ellis, & Wells, 2008; Leyman, De Raedt, Vaeyens, & Philippaerts, 2011) and are assumed to reflect different mechanisms of attention (see Armstrong & Olatunji, 2012). More specifically, the fixation frequency parameter indexes (re)orienting of attention (cf. selection mechanism) and the fixation duration parameter indexes sustained attention at encoding (cf. maintenance mechanism). Relative bias scores (i.e., positive versus negative) were calculated within-subjects, because such indices might be more relevant indicators of depression-associated processing of emotional information than absolute indices comparing emotional with neutral information (Shane & Peterson, 2007). The total fixation frequency on negative words was divided by the total fixation frequency on emotional (positive and negative) words in the emotional scrambled sentences. Analogous calculations were made to obtain a relative bias index for the fixation duration. Note that in the other cognitive tasks we also used relative bias indices (see below). Here, these relative indices of attention bias also control for inter-individual baseline fixation differences due to inter-individual variability in reading performance.

Interpretation bias. A computerized version of the Scrambled Sentences Test (SST; Wenzlaff & Bates, 1998) was used to measure individual differences in the tendency to interpret ambiguous information as either negative or positive. Prior studies with this task revealed differences in interpretative tendencies between depressed and non-depressed samples (e.g., Hedlund & Rude, 1995; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002). In this study, each trial started with a fixation point at the left side of the screen (to elicit left-to-right reading) followed by a *stimulus display* depicting either a neutral or an emotional scrambled sentence. Each sentence was presented at the center of the screen on a single line in black mono-spaced lowercase Arial (font size 25pt) against a white background. In the display part of the trial, participants unscrambled the presented stimulus mentally and as quickly as possible to form grammatically correct and meaningful statements using five of the six words (e.g., “I often visit the theatre” or “I am a born winner”). Upon completion, participants pressed a button to continue to the response part of the trial. Each scrambled sentence was displayed for maximum 8 s and the task automatically continued to the response trial part once the time limit had been expired. In the *response part*, each word of the scrambled sentence was presented along with a number. To reduce social desirable responses, participants reported their unscrambled sentence using the corresponding numbers. The response trial part was omitted when a participant did not form a sentence in time during the display part (5% of the trials). Figure 1 presents the sequence of events in a single trail.

The complete task comprised a practice and a test phase. The practice phase included 5 trials of neutral scrambled sentences to familiarize participants with the task. The test phase included 100 trials equally dispersed over 10 blocks. Each block contained 6 emotional and 4 neutral stimuli presented in a fixed order for each participant. No more than two emotional scrambled sentences were consecutively presented in a block to reduce priming effects. Moreover, we added a cognitive load procedure to prevent deliberate report strategies. Similar to previous research with the SST (e.g., Rude et al., 2002), participants memorized a 6-digit-number before each block (presented on the screen for 5 s) to be recalled at the end of the block. Interpretation bias was indexed by the ratio of negatively unscrambled sentences over the total correctly completed emotional sentences.

Memory bias. In the incidental free recall test, participants were asked to recall the sentences that they had previously constructed during the computerized SST as accurately as possible. A maximum of 5 minutes was allowed for this task. Emotional biases in memory were calculated by dividing the number of recalled negatively unscrambled sentences by the total number of unscrambled emotional sentences recalled.

Eye Tracker

A tower-mounted Eyelink 1000 eye tracking device (SR Research, Mississauga, Ontario, Canada) recorded gaze behavior. Viewing was binocular and eye movements were registered from the right eye only. Fixations were sampled every millisecond and were only considered when longer than 50ms (shorter fixations reflect anticipatory saccades; see also Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Interest areas concerned the negative and positive target words in emotional scrambled sentences and neutral target words in neutral scrambled sentences.

Procedure

Participants were seated at 60 cm from the monitor in a height-adjustable chair. A forehead rest of the eye-tracker minimized head movements. Participants started with the interpretation task which was combined with eye movement registration. To guarantee accurate measurement, a 9-point grid calibration procedure was repeated before each block of the interpretation task and drifts from proper calibration were checked at the start of each trial. The system was recalibrated as necessary. The experimenter recorded the participants' verbal responses (i.e., coded unscrambled sentences, cognitive load) manually without providing feedback. Participants were given the opportunity to take a short break after each test block to ensure optimal concentration. After the interpretation task, participants continued with the incidental free recall test and, finally, they completed the BDI-II (to avoid mood priming). The experimental session lasted approximately 70 min.

Data-Analytic Plan

The data-analysis comprised two steps. First, we calculated bivariate correlations among cognitive bias indices and depression scores to examine associations between these variables. Next, different path models were fitted by full information maximum likelihood estimation using the SEM package in R (Fox, 2006). As noted in the introduction, in Model 0, we used BDI-II scores (exogenous variable) to predict biases in attention, interpretation, and memory (endogenous variables) without any relations among these cognitive processes. In addition to the links in Model 0, Model 1 included a sequence starting with biased selection mechanisms of attention (cf. relative fixation frequency) as a precursor of interpretation bias which in turn predicts a congruent memory bias. In Model 2, BDI-II scores predict biased maintenance of attention (cf. relative fixation duration) and interpretation, which are both associated with biases in memory. Model fit was evaluated with different types of fit measures sensitive to model misspecification and less affected by sample size. In particular, we used the χ^2 test, the Root-Mean-Square Error of Approximation (RMSEA), and the Standard Root Mean Squared Residuals (SRMR) as indexes of overall model fit, the Confirmatory Fit Index (CFI) and Non-normed Fit Index (NNFI) as incremental fit indices, and, finally, the Akaike's Information Criterion (AIC) as a parsimony fit measure. A well-fitting model has a non-significant test statistic on the χ^2 test ($p>.05$), an RMSEA value lower than or equal to 0.06, an SRMR value less than .08, as well as values on the NNFI and CFI that exceed 0.95 (West, Taylor, & Wu, 2012). When path models with competing predictions both attained a good model fit, a χ^2 difference test was conducted and the parsimony of both models was compared using the AIC values favoring the model with a lower value.

Results

Associations Among Cognitive Biases

The correlation pattern is supportive for associations among depressive symptom severity levels, attention, interpretation, and memory biases (see Table 1). Individuals with more severe depression levels fixate more frequently and longer on negative information, endorse more negative than positive meanings, and recall relatively more sentences with a negative valance[2]. Table 2 provides descriptive statistics for the 33% lowest and 33% highest depression scores. Interestingly, differential correlations emerged among different mechanisms of attention and the other processing biases. As predicted, the selection mechanism correlated with interpretation bias but not with memory bias, whereas the maintenance of attention correlated with memory bias and marginally significant with interpretation bias. The mechanisms of attention bias were positively correlated.

The BDI-II scores did not correlate with fixation frequency on neutral words, r=-.06, p>.05, nor with fixation durations on neutral words, r=.01, p>.05. Importantly, this indicates that baseline fixation indices, and thus reading times, did not differ with respect to levels of depressive symptom severity.

Functional Relations Among Cognitive Biases

To address the main research question, the constructed path models assuming interrelations among biased cognitive processes (Model 1 and Model 2) were fitted and compared to a competing path model in which functional relations among biases were omitted (Model 0). Figures 2 and 3 depict the tested path models with the estimates of the path coefficients.

Model 1 versus Model 0. Path analysis yielded a good fit for Model 1, $\chi^2(2)<1$, p=0.9996, CFI=1, NNFI=1.10 and RMSEA=0, SRMR=.001, AIC=16.00. Inspecting the path coefficients, depression levels (BDI-II) predicted both selection bias, γ_{11}=.27 (SE=.12), p<.05, and interpretation bias, γ_{21}=.56 (SE=.10), p<.001, but not memory bias, γ_{31} = -0.01 (SE=.13), p=.93. As expected, biased selection of attention was associated with interpretation bias, β_{21}=.19 (SE=.10), p<.05, which in turn was associated with memory bias, β_{32}=.55 (SE=.13), p<.001. In direct support of the combined cognitive biases hypothesis, a poor fit for Model 0 was observed on all fit measures, $\chi^2(4)$=20.34, p<.001, CFI=.73, NNFI=0.60, RMSEA=0.24, SRMR=.13, AIC=32.34, though the modeled pathways were significant.

Model 2 versus Model 0. The path analysis revealed an excellent fit for Model 2 on all fit indices, $\chi^2(3)<1$, p=.87, CFI=1, NNFI=1.07, RMSEA=0, SRMR=.03, AIC=14.68. Depression (BDI-II) scores were significantly associated with attention bias in maintenance of attention, γ_{11}=.25 (SE=.12), p<.05, and interpretation bias, γ_{21}=.61 (SE=.09), p<.001. Both maintenance, β_{31}=.24 (SE=.10), p<.05, and interpretation bias, β_{32}=.49 (SE=.10), p<.001, were in turn associated with memory bias. Again, providing evidence for the combined cognitive biases hypothesis, a poor model fit for Model 0, $\chi^2(4)=22.88$, $p<.001$, CFI=.70, NNFI=0.55, RMSEA=0.26, SRMR=.14, AIC=34.88, was observed.

Discussion

A wide range of empirical findings demonstrate that emotional biases in attention, interpretation, and memory are involved in the onset, maintenance, and recurrence of depressive symptoms. To date, scientific insight in how these biased cognitive processes influence each other remains limited. This study tested the dependence of memory on depression-associated biases in distinct attention mechanisms and interpretation. Participants completed an interpretation task while their eye movements were recorded. Memory for the constructed interpretations was measured by a subsequent incidental free recall test. Results showed significant correlations among cognitive bias indices and depression levels. More importantly, path analyses revealed that models with the predicted functional relations among processing biases attained good and superior model fits compared to path models without functional relations among processing biases. Thereby, the results provide evidence for the combined cognitive biases hypothesis at subclinical symptom levels of depression. The findings are discussed in turn.

The present results lend support for associations among depression-associated biases at different levels of processing. As noted, cognitive models of depression (e.g., Clark et al., 1999; Joormann et al., 2007; Williams et al., 1988) postulate that emotional biases emerge across different modalities of processing (i.e., attention, memory) so that this should have an impact on different cognitive tasks and bias measures. The reported results show that individuals with higher levels of depressive symptoms devote attention more frequently (selection mechanism) and for longer periods of time (maintenance mechanism) to negative information compared to positive material. Also, they make more negative interpretations and recall more negative memories. Interestingly, the observed correlation pattern also showed the expected differential relations among attention bias indices, interpretation, and memory. We found that the relative fixation frequency was correlated with interpretation bias, whereas the relative fixation duration was correlated with the extent to which negative interpretations were recalled. This is in line with the idea that the attention bias indices applied in this study reflect different mechanisms of attention (see Chun et al., 2011), with the relative fixation frequency reflecting biases in the selection mechanism of attention and the relative fixation duration reflecting biases in the maintenance of attention.

Evidence for the main tenet of the combined cognitive biases hypothesis was obtained from substantial better model fits for path models including the predicted functional relations among cognitive biases compared to path models assuming independent cognitive processes. The findings show that emotional biases in distinct attention mechanisms and interpretation regulate what is remembered via different pathways. The modeled pathways indicate that selective orienting of attention in favor of negative information is followed by more negative interpretations of the presented information, because one has to actually look at the word one is choosing (i.e., select the relevant information) to complete the sentence (i.e., construct meaning). In turn, interpretation bias sets the stage for congruent biases in memory, in that individuals who make more negative sentences will recall more of them. As such, memory bias reflects interpretive choices. Moreover, memory for emotional information was also related to emotional biases in the maintenance of attention, in that a greater bias in this attention mechanism predicted improved memory for negative material. Importantly, the modeled functional relations in Model 1 and Model 2 among biases in attention, interpretation, and memory remained significant when taking into account the relation between each bias and depressive symptom severity levels. This suggests that the observed relations among biases in attention, interpretation, and memory are not merely a by-product of influences of a joint third variable, being depressive symptom severity.

These observations extend previous research in subclinical samples showing that memory for emotional information can be explained by biases in attention at elaborative stages (Ellis et al., 2011; Koster et al., 2010) and by negative biases in interpretation processes (Hertel & El-Messidi, 2006). To follow up on the findings reported in this article, we recently conducted a study to provide further empirical support for the indirect effect of attention on memory bias via interpretation processes (Everaert, Tierens, Uzieblo, & Koster, 2013). Replicating the current findings, we observed that a bias in attention (measured by a spatial cueing task) is related to a congruent bias in interpretative choices (measured by a scrambled sentences test) which are in turn reflected in memory (measured by an incidental free recall task). In sum, the accumulated data relevant to the combined cognitive biases hypothesis in depression demonstrates that memory for emotional information depends on emotional biases in attention and interpretation processes.

The empirical evidence for the modeled pathways supports specific theoretical claims by cognitive models of depression on interrelations among emotional processing biases and depression levels (Ingram, 1984; Joormann et al., 2007; Williams et al., 1988, 1997). However, note that the tested path models, Model 1 and Model 2, derived from different cognitive models with competing predictions can be complementary. Although it is realized that most cognitive processes are not unitary (e.g., attention; see Chun et al., 2011), cognitive models are underspecified in the extent to which they hypothesize about the interplay among specific biased components of cognitive processes. For instance, it is found that biases in attention occur at the later stages of processing (De Raedt & Koster, 2010); however, models do typically not distinguish between biases in selective (re)orienting of attention and biases in the maintenance of attention, when explaining the impaired disengagement from negative information. Analogously, different mechanisms or components are involved in interpretation bias (e.g., automatic or effortful activation and selection of meanings; see Wisco, 2009) and in memory bias (e.g., encoding, consolidation/storage, retrieval). Empirical studies as reported here might inform theoretical models to increase their specificity on the interrelations (e.g., the overlap and unique features) among specific components of biased attention, interpretation, and memory processes.

Besides their theoretical relevance, the present findings have implications for the understanding of the fundamental mechanisms of cognition – emotion interactions. The results cast light on the interplay among mechanisms that underlie (in)effective emotion regulation across the spectrum of depressive symptom severity levels. It has been argued that depression-associated biases in attention, interpretation, and memory processes hamper adaptive emotion regulation strategies (e.g., reappraisal) which accordingly maintains or aggravates depressive symptoms, in particular negative mood (Joormann & D'Avanzato, 2010). This means that the cognitive biases under investigation here contribute to the onset, maintenance, or recurrence of depressive symptoms via their influence on how individuals at-risk for depression (e.g., subclinically or formerly depressed) respond to emotional events. The current findings suggest that, when subclinically depressed persons are exposed to emotion-eliciting events (e.g., a job interview), they tend to orient attention more frequently towards negative than positive cues (e.g., frowning eyebrows of one of the assessors) and dwell longer on this negative information. These difficulties disengaging attention from the processing of this negative material compromises reorienting attention as an anticipatory emotion regulation strategy (e.g., focusing on the other assessors) and may lead to negative interpretations (e.g., “I am making a bad impression”, “they think I am not capable for the job”). These initial interpretations could in turn be maintained by rigid biases in interpretation processes that hinder reappraisal of the situation to modify the initial thoughts. Dysfunctional memory representations could be consolidated as such (e.g., “I am worthless”), setting the stage for mood-congruent memory bias and jeopardizing the ability to use mood-incongruent recall to repair negative mood in the future. In this way, biased cognitive processes and emotion regulation strategies might interact to maintain or worsen symptoms of depression, as such further increasing the risk to relapse or develop first-onset clinical conditions.

Moreover, the results provide new directions for further developments in the application of cognitive bias modification techniques. These techniques can offer an additional tool to reduce vulnerability to depression because cognitive-behavioral therapies might be hampered in modifying underlying negative schemas (i.e., a set of dysfunctional beliefs stored in memory) given that selection, encoding, and elaboration on information is strongly favored towards schema-congruent material (Baert, Koster, & De Raedt, 2011). The present findings suggest that modifying one aspect of processing bias (e.g., attention) might change the later processing of this information at other modalities (e.g., interpretation). This suggests that when a negative bias at the early stages of processing can be effectively reduced (e.g., at the attention level), this could normalize the information processing at later stages. Eventually, this might change negative schemata so that dysfunctional beliefs transform into more adaptive views. Given that these cognitive bias modification procedures improve the processing of schema-incongruent information, they might facilitate recovery from depression and protect against relapse or recurrence of depressive symptoms when applied as an add-on to an active treatment or as a prevention tool, respectively.

Some limitations of this study should be addressed. The cross-sectional design precludes conclusions regarding causality. Future research should test the hypothesized directions of the modeled pathways through experimental manipulation (see also below). Another limitation concerns aspects of the study design that forces using relative bias indices that compare the processing of negative with positive material. This is because the emotional items of the scrambled sentences test (i.e., the eye tracking task) present one negative and one positive target word within a specific and a meaningful context that does not correspond with the topics presented in neutral scrambled sentences. In addition, the emotional target words are not matched with target words in neutral scrambled sentences on critical lexical variables (see method section). Based on these task features, relative bias indices are preferred (based on data within scrambled sentences) instead of bias indices that compare the processing of negative or positive with neutral words (based on data between scrambled sentences). Although this approach cannot determine whether the observed effects are driven by a greater emphasis on negative material or a lack of responsiveness to positive material, research has shown that relative bias indices might be more robust markers of depression-associated processing than absolute indices (Shane & Peterson, 2007).

Several directions for future research can be discerned. It is clear that more research considering a broader set of cognitive mechanisms in different depressed samples is needed to unravel the complex interplay among cognitive biases. As the present study adds further evidence for the combined cognitive biases hypothesis at subclinical depression levels, similar research testing functional relations among processing biases across different samples representing different stadia of the depression course is necessary. This is because the interplay among biased cognitive processes might change over time as a function of the experience of becoming and being depressed (e.g., increasing sad affect, negative thoughts) which could affect the magnitude of one or more cognitive biases (e.g., memory). As such, the interrelations among biases might be stronger as the number of depressive episodes increases (Teasdale & Barnard, 1993). Also, functional relations with other critical cognitive processes (e.g., components of cognitive control) have not been investigated yet and also more research testing comprehensive models linking aspects of emotion processing and emotional dysregulation is needed (e.g., Llewellyn, Dolcos, Jordan, Rudolph, & Dolcos, 2013). Moreover, as noted, future research should test causal relations between different cognitive biases through experimental manipulation. In this respect, cognitive bias modification procedures provide the necessary tools to test causal pathways (see Koster, Fox, & MacLeod, 2009). Noteworthy are studies by Salemink et al. (2010) and Tran et al. (2011) that have investigated the influence of interpretation on memory bias by inducing negative and positive interpretive biases in nonclinical samples. However, many other links (e.g., how memory bias may guide attention) between biased cognitive processes need future empirical consideration.

In conclusion, this study investigated how mechanisms of attention bias and interpretation bias regulate memory at subclinical depression levels. We found evidence for associations among biased cognitive processes that emerge across different levels of processing. Moreover, the results revealed that memory depends on the manner in which emotional information is attended and interpreted. The findings offer direct evidence for the combined cognitive biases hypothesis and indicate that future research should take into account such interrelations.

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References

Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review, 32*(8), 707-723. doi: 10.1016/j.cpr.2012.09.004

Baert, S., Koster, E. H. W., & De Raedt, R. (2011). Modification of information-processing biases in emotional disorders: Clinically relevant developments in experimental psychopathology. *International Journal of Cognitive Therapy, 4*(2), 208-222. doi: 10.1521/ijct.2011.4.2.208

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory - II*. San Antonio, TX: Psychological Corporation.

Blaut, A., Paulewicz, B., Szastok, M., Prochwicz, K., & Koster, E. (2013). Are attentional bias and memory bias for negative words causally related? *Journal of Behavior Therapy and Experimental Psychiatry, 44*(3), 293-299. doi: 10.1016/j.jbtep.2013.01.002

Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011). A taxonomy of external and internal attention. *Annual Review of Psychology, 62*, 73-101. doi: 10.1146/annurev.psych.093008.100427

Chun, M. M., & Turk-Browne, N. B. (2007). Interactions between attention and memory. *Current Opinion in Neurobiology, 17*(2), 177-184. doi: 10.1016/j.conb.2007.03.005

Clark, D. A., Beck, A. T., & Alford, B. A. (1999). *Scientific foundations of cognitive theory and therapy of depression*. New York: John Wiley and Sons Ltd.

De Raedt, R., & Koster, E. H. W. (2010). Understanding vulnerability for depression from a cognitive neuroscience perspective: A reappraisal of attentional factors and a new conceptual framework. *Cognitive, Affective, & Behavioral Neuroscience, 10*(1), 50-70. doi: 10.3758/CABN.10.1.50

Duyck, W., Desmet, T., Verbeke, L. P. C., & Brysbaert, M. (2004). WordGen: A tool for word selection and nonword generation in Dutch, English, German, and French. *Behavior Research Methods Instruments & Computers, 36*(3), 488-499. doi: 10.3758/BF03195595

Ellis, A. J., Beevers, C. G., & Wells, T. T. (2011). Attention allocation and incidental recognition of emotional information in dysphoria. *Cognitive Therapy and Research, 35*(5), 425-433. doi: 10.1007/s10608-010-9305-3

Everaert, J., Koster, E. H. W., & Derakshan, N. (2012). The combined cognitive bias hypothesis in depression. *Clinical Psychology Review, 32*(5), 413-424. doi: 10.1016/j.cpr.2012.04.003

Everaert, J., Tierens, M., Uzieblo, K., & Koster, E. H. (2013). The indirect effect of attention bias on memory via interpretation bias: Evidence for the combined cognitive bias hypothesis in subclinical depression. *Cognition & Emotion*, 1-10. doi: 10.1080/02699931.2013.787972

Fox, J. (2006). Structural equation modeling with the sem package in R. *Structural Equation Modeling: A Multidisciplinary Journal, 13*(3), 465-486. doi: 10.1207/s15328007sem1303_7

Gotlib, I. H., Kasch, K. L., Traill, S., Joormann, J., Arnow, B. A., & Johnson, S. L. (2004). Coherence and specificity of information-processing biases in depression and social phobia. *Journal of Abnormal Psychology, 113*(3), 386-398. doi: 10.1037/0021-843x.113.3.386

Hedlund, S., & Rude, S. S. (1995). Evidence of latent depressive schemas in formerly depressed individuals. *Journal of Abnormal Psychology, 104*(3), 517-525. doi: 10.1037//0021-843X.104.3.517

Hertel, P. T., & Brozovich, F. (2010). Cognitive habits and memory distortions in anxiety and depression. *Current Directions in Psychological Science, 19*(3), 155-160. doi: 10.1177/0963721410370137

Hertel, P. T., & El-Messidi, L. (2006). Am I blue? Depressed mood and the consequences of self-focus for the interpretation and recall of ambiguous words. *Behavior Therapy, 37*(3), 259-268. doi: 10.1016/j.beth.2006.02.001

Hirsch, C. R., Clark, D. M., & Mathews, A. (2006). Imagery and interpretations in social phobia: Support for the combined cognitive biases hypothesis. *Behavior Therapy, 37*(3), 223-236. doi: 10.1016/j.beth.2006.02.001

Ingram, R. E. (1984). Toward an information-processing analysis of depression. *Cognitive Therapy and Research, 8*(5), 443-477. doi: 10.1007/BF01173284

Joormann, J., & D'Avanzato, C. (2010). Emotion regulation in depression: Examining the role of cognitive processes. *Cognition & Emotion, 24*(6), 913-939. doi: 10.1080/02699931003784939

Joormann, J., Yoon, K. L., & Zetsche, U. (2007). Cognitive inhibition in depression. *Applied & Preventive Psychology, 12*(3), 128-139. doi: 10.1016/j.appsy.2007.09.002

Kellough, J. L., Beevers, C. G., Ellis, A. J., & Wells, T. T. (2008). Time course of selective attention in clinically depressed young adults: An eye tracking study. *Behaviour Research and Therapy, 46*(11), 1238-1243. doi: 10.1016/j.brat.2008.07.004

Koster, E. H. W., De Raedt, R., Leyman, L., & De Lissnyder, E. (2010). Mood-congruent attention and memory bias in dysphoria: Exploring the coherence among information-processing biases. *Behaviour Research and Therapy, 48*(3), 219-225. doi: 10.1016/j.brat.2009.11.004

Koster, E. H. W., Fox, E., & MacLeod, C. (2009). Introduction to the special section on cognitive bias modification in emotional disorders. *Journal of Abnormal Psychology, 118*(1), 1-4. doi: 10.1037/a0014379

Leyman, L., De Raedt, R., Vaeyens, R., & Philippaerts, R. M. (2011). Attention for emotional facial expressions in dysphoria: An eye-movement registration study. *Cognition & Emotion, 25*(1), 111-120. doi: 10.1080/02699931003593827

Llewellyn, N., Dolcos, S., Jordan, A. D., Rudolph, K. D., & Dolcos, F. (2013). Reappraisal and suppression mediate the contribution of regulatory focus to anxiety in healthy adults. *Emotion, 13*(4), 610-615. doi: 10.1037/A0032568

Matt, G. E., Vazquez, C., & Campbell, W. K. (1992). Mood-congruent recall of affectively toned stimuli - A meta-analytic review. *Clinical Psychology Review, 12*(2), 227-255. doi: 10.1016/0272-7358(92)90116-P

Peckham, A. D., McHugh, R. K., & Otto, M. W. (2010). A Meta-analysis of the magnitude of biased attention in depression. *Depression and Anxiety, 27*(12), 1135-1142. doi: 10.1002/da.20755

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*(3), 372-422. doi: 10.1037/0033-2909.124.3.372

Rayner, K., Kambe, G., & Duffy, S. A. (2000). The effect of clause wrap-up on eye movements during reading. *Quarterly Journal of Experimental Psychology, 53A*(4), 1061-1080. doi: 10.1080/02724980050156290

Rayner, K., Sereno, S. C., Morris, R. K., Schmauder, A. R., & Clifton, C. (1989). Eye movements and on-line language comprehension processes. *Language and Cognitive Processes, 4*(3-4), Si21-Si49. doi: 10.1080/01690968908406362

Rude, S. S., Wenzlaff, R. M., Gibbs, B., Vane, J., & Whitney, T. (2002). Negative processing biases predict subsequent depressive symptoms. *Cognition & Emotion, 16*(3), 423-440. doi: 10.1080/02699930143000554

Salemink, E., Hertel, P., & Mackintosh, B. (2010). Interpretation training influences memory for prior interpretations. *Emotion, 10*(6), 903-907. doi: 10.1037/a0020232

Schotter, E. R., Angele, B., & Rayner, K. (2012). Parafoveal processing in reading. *Atten Percept Psychophys, 74*(1), 5-35. doi: 10.3758/s13414-011-0219-2

Shafer, A. T., & Dolcos, F. (2012). Neural correlates of opposing efects of emotional distraction on perception and episodic memory: An event-related fMRI investigation. *Frontiers in Integrative Neuroscience, 6*, 1-15. doi: 10.3389/fnint.2012.00070

Shane, M. S., & Peterson, J. B. (2007). An evaluation of early and late stage attentional processing of positive and negative information in dysphoria. *Cognition & Emotion, 21*(4), 789-815. doi: 10.1080/02699930600843197

Teasdale, J., & Barnard, P. (1993). *Affect, cognition and change*. Hove: Lawrence Erlbaum Associates.

Tran, T. B., Hertel, P. T., & Joormann, J. (2011). Cognitive bias modification: Induced interpretive biases affect memory. *Emotion, 11*(1), 145-152. doi: 10.1037/a0021754

Van der Does, A. J. W. (2002). *Handleiding bij de Nederlandse versie van de Beck Depression Inventory - second edition (BDI-II-NL). [The Dutch version of the Beck Depresion Inventory-II]*. Lisse, NL: Swets & Zeitlinger.

Van der Does, A. J. W. (2005). Thought suppression and cognitive vulnerability to depression. *British Journal of Clinical Psychology, 44*, 1-14. doi: 10.1348/014466504x19442

Wenzlaff, R. M., & Bates, D. E. (1998). Unmasking a cognitive vulnerability to depression: How lapses in mental control reveal depressive thinking. *Journal of Personality and Social Psychology, 75*(6), 1559-1571. doi: 10.1037//0022-3514.75.6.1559

West, S. G., Taylor, A. B., & Wu, W. (2012). Model fit and model selection in structural equation modeling. In R. H. Hoyle (Ed.), *Handbook of structural equation modeling*. New York: Guilford Publications.

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1988). *Cognitive psychology and emotional disorders*. New York: John Willey and Sons Ltd.

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1997). *Cognitive psychology and emotional disorders*. Chichester: John Wiley and Sons Ltd.

Wisco, B. E. (2009). Depressive cognition: Self-reference and depth of processing. *Clinical Psychology Review, 29*(4), 382-392. doi: 10.1016/j.cpr.2009.03.003

Footnotes

[1] Word length: $M_{\text{negative words}}$ = 8.42 ($SD_{\text{negative words}}$ = 1.90), $M_{\text{positive words}}$ = 8.37 ($SD_{\text{positive words}}$ = 2.12); Word frequency (log frequency per million): $M_{\text{negative words}}$ = 1.07 ($SD_{\text{negative words}}$ = 0.56), $M_{\text{positive words}}$ = 1.22 ($SD_{\text{positive words}}$ = 0.69).

[2] Absolute levels of recall. For the lowest 33% BDI-II scores, the mean number of recalled positive items was 3.52 (1.27) and recalled negative items 1.13 (1.22). For the highest 33% BDI-II scores, the mean number of recalled positive items was 3.17 (1.74) and recalled negative items 2.30 (1.92).

Table 1.

Correlations among Cognitive Bias Indices and Depression Levels

Variable	Attention bias: Selection	Attention bias: Maintenance	Interpretation bias	Memory bias
BDI-II	.27*	.25*	.61***	.33**
Attention bias				
Selection	/	.49***	.34**	.18
Maintenance		/	.22†	.35**
Interpretation bias			/	.54***
Memory bias				/

Note1. BDI-II = Beck Depression Inventory – II.

Note2. *p<.05; **p<.01; ***p<.001; †p<.10

Table 2.

Descriptive Statistics for Cognitive Bias Indices

	BDI-II scores	
Variable	Lowest 33%	Highest 33%
Attention bias		
Selection	48.70 (3.67)	51.11 (5.27)
Maintenance	49.18 (2.57)	51.18 (3.98)
Interpretation bias	22.50 (13.03)	48.49 (16.37)
Memory bias	21.51 (22.89)	39.75 (27.01)

Note1. Standard deviations are shown between parentheses.

Note2. BDI-II = Beck Depression Inventory – II.

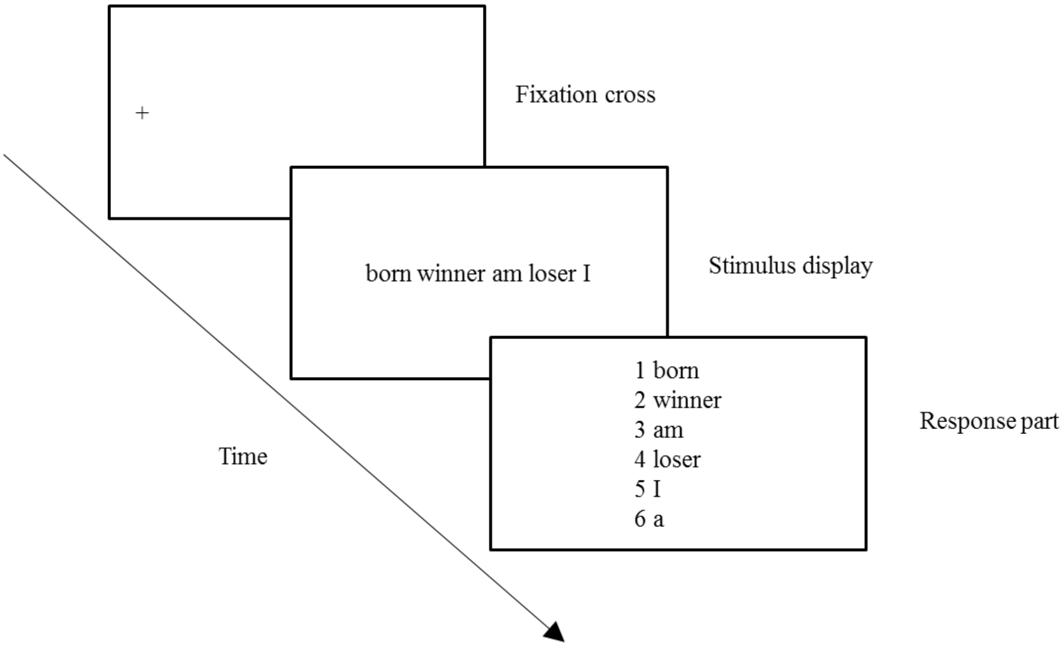


Figure1. Example trial display.

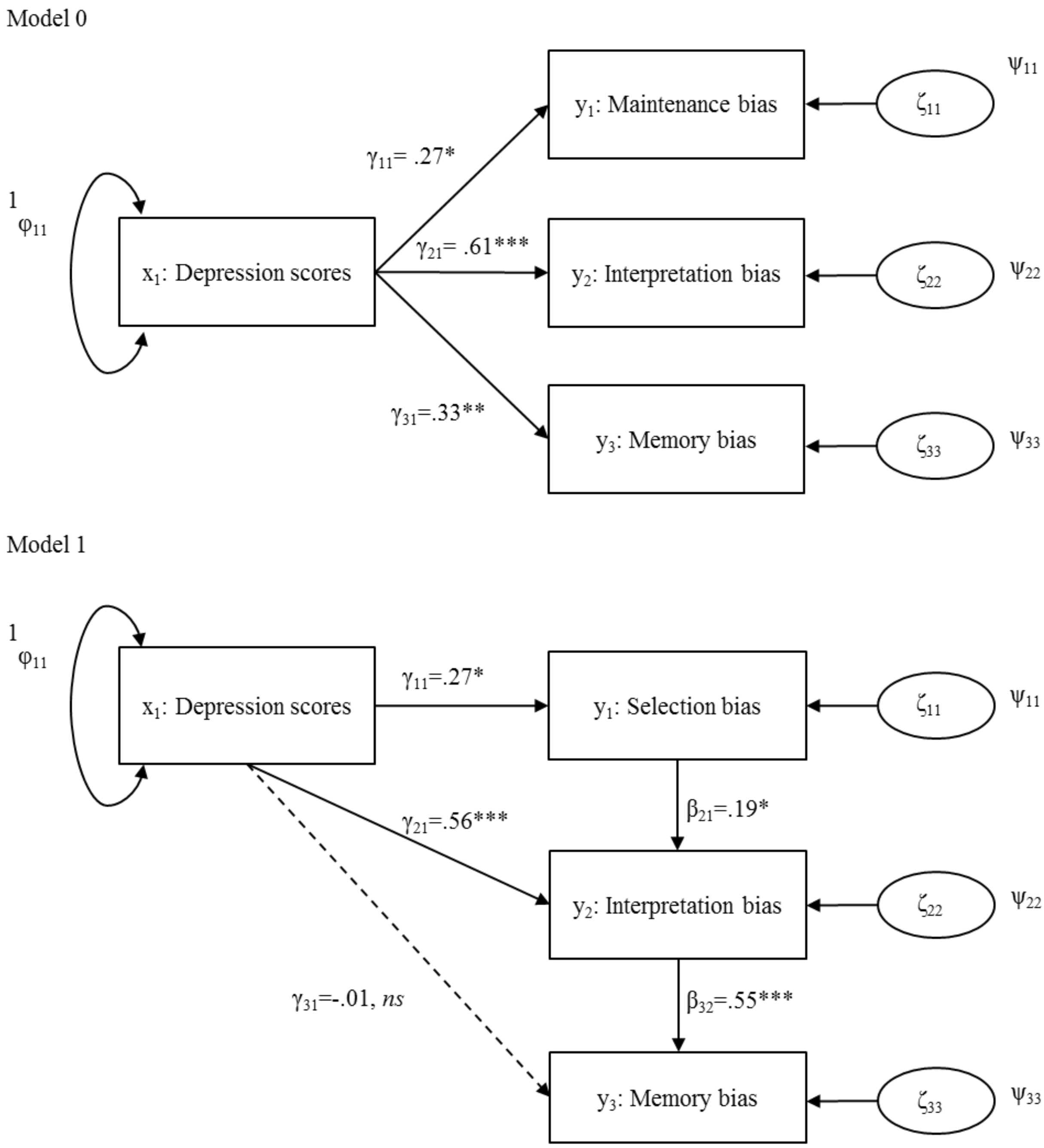
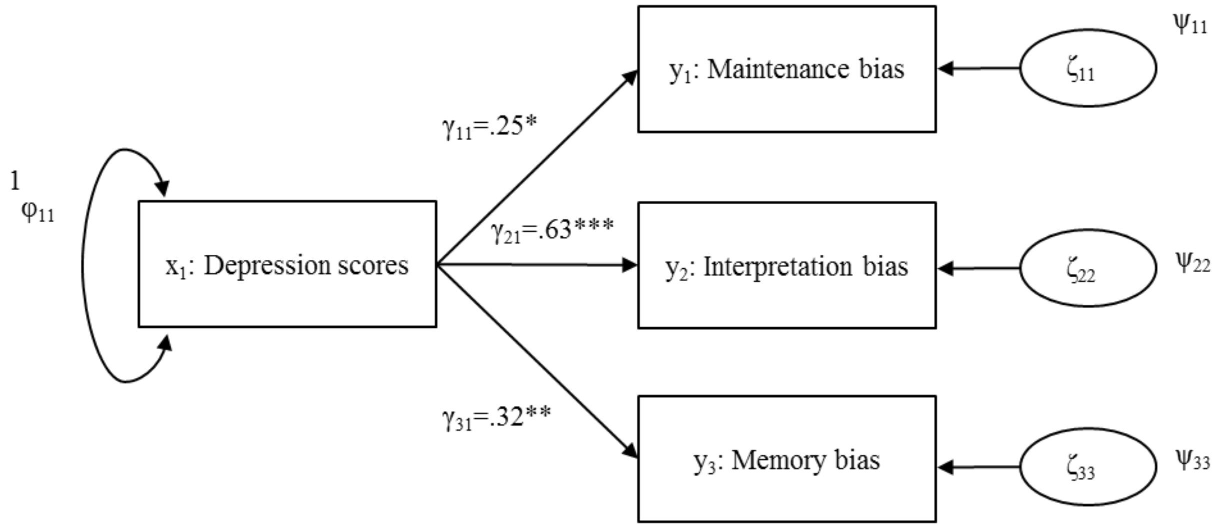


Figure2. Tested path models including selection mechanisms of attention

Model 0



Model 2

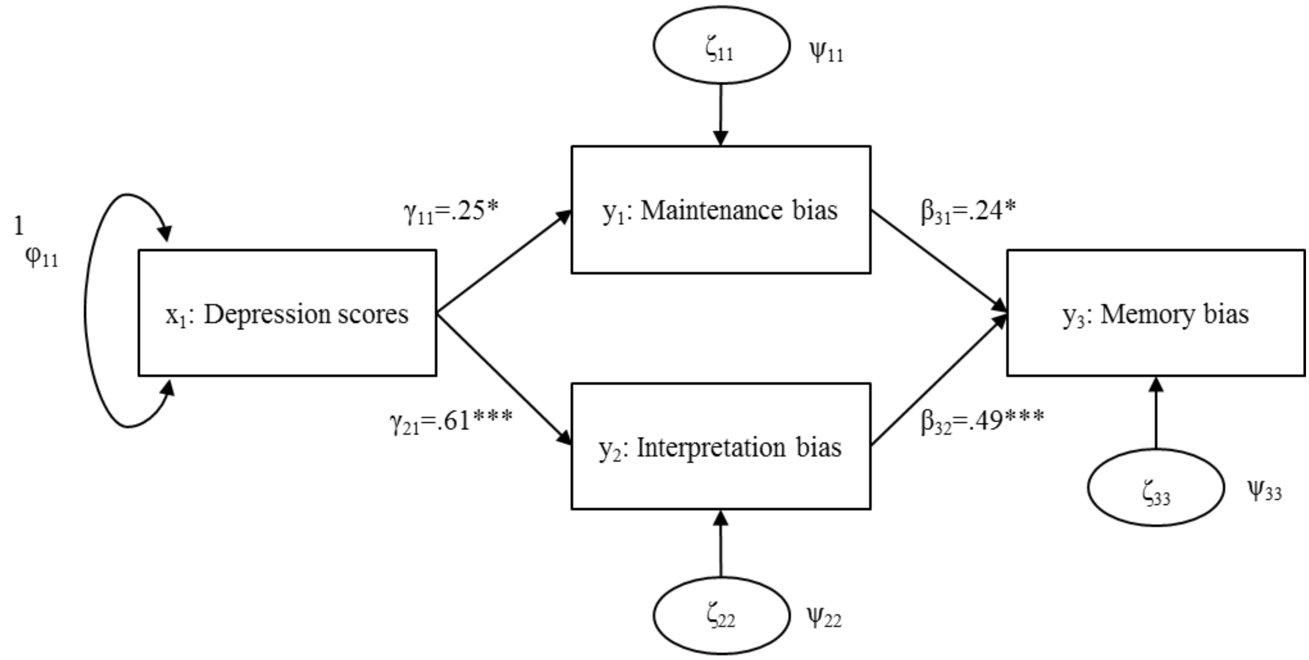


Figure3. Tested path models including maintenance mechanisms of attention