

Individual differences in cognitive control over emotional material modulate cognitive biases linked to depressive symptoms

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Abstract

Deficient cognitive control over emotional material and cognitive biases are important mechanisms underlying depression, but the interplay between these emotionally distorted cognitive processes in relation to depressive symptoms is not well understood. This study investigated the relations among deficient cognitive control of emotional information (i.e., inhibition, shifting, and updating difficulties), cognitive biases (i.e. negative attention and interpretation biases), and depressive symptoms. Theory-driven indirect effect models were constructed, hypothesizing that deficient cognitive control over emotional material predicts depressive symptoms through negative attention and interpretation biases. Bootstrapping analyses demonstrated that deficient inhibitory control over negative material was related to negative attention bias which in turn predicted a congruent bias in interpretation and subsequently depressive symptoms. Both shifting and updating impairments in response to negative material had an indirect effect on depression severity through negative interpretation bias. No evidence was found for direct effects of deficient cognitive control over emotional material on depressive symptoms. These findings may help to formulate an integrated understanding of the cognitive foundations of depressive symptoms.

Keywords: cognitive control, cognitive bias, depression.

Introduction

Depression is a common psychological disorder associated with a severe personal and societal burden (Kessler & Wang, 2009). Efforts to identify its underlying mechanisms are therefore particularly important to advance understanding of the disorder and current treatments. Intensive research programs during the past several decades have uncovered abnormalities in processing of emotional information that are implicated in the onset and maintenance of depressive symptoms. Specifically, impairments in cognitive control over emotional material and negatively biased cognitive processes seem to differentiate healthy from depressive emotional functioning (for a review see Gotlib & Joormann, 2010).

Cognitive control refers to a set of separable, yet related, processes that regulate the contents of working memory (WM), a temporary storage system that is crucial in guiding goal-directed behavior in daily life (Hasher & Zacks, 1988; Miyake et al., 2000). Depression is characterized by distortions in multiple cognitive control components when processing emotional material. Depressed individuals have difficulties in *inhibiting* negative information from WM (Joormann, Yoon, & Zetsche, 2007), *shifting* between emotionally negative and non-emotional mental sets (De Lissnyder, Koster, Derakshan, & De Raedt, 2010), and *updating* WM by removing no longer relevant negative material to replace it by new material (Levens & Gotlib, 2010). These difficulties in cognitive control over emotional material predict prospective increases in depressive symptoms (De Lissnyder et al., 2012; Pe, Brose, Gotlib, & Kuppens, 2015; Zetsche & Joormann, 2011).

Depression-linked cognitive biases in attention and interpretation result in exaggerated processing of negative over positive material. Depressed individuals experience difficulties in disengaging attention from processing negative material (Armstrong & Olatunji, 2012) and infer more negative than positive interpretations from ambiguous information (for a review, see Wisco, 2009). Research has shown that these cognitive biases predict one's emotional

response to stressors and future depressive symptoms (e.g., Clasen, Wells, Ellis, & Beevers, 2013; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002).

Although much has been discovered about depression-linked difficulties in cognitive control of emotional material and cognitive biases, relatively little is known about the interplay among these distorted cognitive processes (Everaert, Koster, & Derakshan, 2012). Theorists have proposed that deficient cognitive control when processing emotional material operates as overarching mechanism across cognitive biases to maintain depressive symptoms (Hertel, 1997; Joormann et al., 2007). Cognitive accounts of depression hypothesize that problems in inhibitory control cause difficulties in limiting the access of irrelevant negative information into WM and hinder removal of negative content from WM that is no longer relevant. These impairments in cognitive control over emotional material are assumed to underlie difficulties in disengaging attention from negative information, which results in enhanced elaboration of this material and a negative interpretation bias (Joormann et al., 2007). These models propose that individual differences in inhibition and updating of negative material have an indirect effect on depressive symptoms through their influence on negative biases in attention and interpretation. The role of shifting, however, is less well described.

Despite theoretical advances, research testing relations among distorted cognitive processes in depression is at the early stages. While studies have shown that a negative attention bias regulates depression-related interpretation bias (Everaert, Duyck, & Koster, 2014), little research has linked difficulties in cognitive control over emotional material to such negative biases in cognitive processes. One study that partially addressed this issue found that depression-related deficits in attentional control modulated the interpretation of emotional material (Sanchez, Everaert, De Putter, Mueller, & Koster, 2015). However, further empirical scrutiny is required to advance knowledge on the relations among multiple

cognitive control processes that operate on emotional material, cognitive biases, and depressive symptoms.

This cross-sectional study was designed to investigate the interplay among individual differences in deficient cognitive control over emotional material, cognitive biases, and depression severity in a theory-driven manner. The objective was to evaluate the prediction that cognitive control difficulties in response to negative material are related to depressive symptoms via negative attention and interpretation biases, separately for deficient inhibition, shifting, and updating. The study utilized established experimental procedures in a nonclinical sample of individuals with varying depressive symptom levels because the demanding study protocol was less suitable for a clinical sample. In this way, this study aimed to provide a first empirical test of the hypothesized relations among these critical cognitive factors in depression.

Method

Participants

A total of 119 participants (101 women) were recruited from the research participant pool based on prescreening of depression scores obtained prior to this study. All individuals who filled out the prescreening were allowed to participate. All participants were native Dutch speakers with normal or corrected-to-normal vision. They provided informed consent and received course credits or 15 euro. The institutional review board approved the study protocol.

Depression and anxiety symptoms

Depressive symptom severity was reassessed at testing with the Dutch Beck Depression Inventory – Second Edition (BDI-II; Van der Does, 2002). Participants indicated the extent to which they suffered from depressive symptoms in the past two weeks. The BDI-II has good psychometric properties (Van der Does, 2002). The internal consistency was

$\alpha=.93$. Moreover, anxiety was measured using the anxiety scale of the Dutch Depression and Anxiety Stress Scale (DASS-A; de Beurs, Van Dyck, Marquenie, Lange, & Blonk, 2001). Participants indicated the extent to which they have experienced the negative emotional state of anxiety over the past week. The internal consistency was $\alpha=.90$.

Assessment of cognitive control over emotional material

Stimuli. The cognitive control tasks used gray-scaled emotional face images drawn from the Karolinska Directed Emotional Faces database (Lundqvist, Flykt, & Öhman, 1998) based on identification accuracy (hit rates > 80%), intensity, and arousal ratings (evaluated on 9-point scales) from validation data (Goeleven, De Raedt, Leyman, & Verschuere, 2008). For the Affective Shift Task, 12 happy and 12 angry facial expressions (24 unique actors; 12 women) originally used by De Lissnyder et al. (2010) were retrieved. The happy and angry faces were matched on intensity ($M_{\text{happy}}=6.69$, $SD=3.89$; $M_{\text{angry}}=6.23$, $SD=1.66$) and arousal ($M_{\text{happy}}=1.59$, $SD=2.01$; $M_{\text{angry}}=3.82$, $SD=1.95$). For the emotional 2-back task, 60 face images (20 actors; 10 women) were selected for this study. Twenty faces depicted happy ($M_{\text{intensity}}=5.94$, $SD=0.83$; $M_{\text{arousal}}=3.63$, $SD=0.48$), 20 angry ($M_{\text{intensity}}=6.15$, $SD=0.73$; $M_{\text{arousal}}=3.75$, $SD=0.60$), and 20 neutral ($M_{\text{intensity}}=5.10$, $SD=0.34$; $M_{\text{arousal}}=2.54$, $SD=0.22$) expressions. The angry and happy faces were matched on intensity and arousal, all F 's < 1. Angry faces were selected because this type of facial expressions unambiguously communicate (social) rejection to the viewer which is directly relevant to depressed individuals' fear of social rejection (Barnett & Gotlib, 1988).

Affective Shift Task (AST; De Lissnyder et al., 2010). The AST, an emotional version of the task-switching paradigm developed by Whitmer and Banich (2007), indexed inhibition and shifting in response to emotional material. The task required participants to perform odd-one-out searches according to a cued stimulus dimension. At each trial, a cue word ('emotion', 'gender', or 'color') informed participants about the task-relevant stimulus

dimension. The cue was presented for 500 ms. After offset, four facial expressions appeared in a squared grid (2×2 matrix). Each of the presented faces could differ from the other faces on three distinct stimulus dimensions, namely emotion (angry or happy), gender (male or female), and color (dark grey or light grey). Participants were instructed to search and locate the face that differed from the other faces based on the cued stimulus dimension as fast and accurately as possible. The target/deviant face was randomly assigned to one of the four positions in the grid. Within a stimulus display, each face differed from the others on only one dimension and deviants on all of the three dimensions were present (always including one different face regarding emotion, gender, and color). The faces were presented until response. Responses were registered using the numerical keyboard. The next trial started after 100 ms. All participants first completed a practice block and then two 108-trial test blocks. The test blocks presented programmed trial types that consisted of fixed sequences of multiple cued dimensions/trials that can be used to disentangle inhibition and shifting (see Table 1).

Inhibition and shifting indices. An index of *inhibitory control* over negative material was obtained by calculating a negative priming index using the inhibitory trial types. Inhibitory trial types presented a sequence of three trials such that the cued dimension on the last trial n was different from the cued dimension on the preceding trial ($n-1$) but the same as two trials back ($n-2$; e.g., emotion–gender–emotion). A negative priming index was computed using RTs on inhibitory trial types on which participants ignored angry faces on trial $n-2$ and focused on angry faces on trial n minus RTs on inhibitory trial types on which participants ignored angry faces on both trials n and $n-2$. These trial types involved two task switches (i.e., from and to trial $n-1$) and the difference score provides a measure not confounded by shifting abilities.

An index of *shifting ability* in response to angry material was obtained by comparing RTs on not-inhibitory trial types that involved a task-switch from trial $n-1$ to trial n with RTs

on repeat trial types that required the use of the same task set in two consecutive trials. To calculate an index of shifting in response to angry stimuli, trial types were considered on which participants shifted from angry stimuli to non-emotional gender information, and vice versa. An integrative index was created by comparing the time to shift from the emotion-angry dimension to a non-emotional dimension with the time to shift from a non-emotional dimension to the emotion-angry dimension (see Table 1). A higher score reflected slower shifting from and faster shifting to negative material.

Emotional 2-back task. An emotional 2-back task was used to index updating of negative information (Levens & Gotlib, 2010). In this task, face images were successively presented prompting participants to indicate whether the facial expression was the same (match trials) or different (no-match trials) from two trials back. Each face image was presented for 2000 ms with an inter-trial interval of 2500 ms. Face images were presented in random order.¹ For the first two trials in each block participants were asked to view the faces and to withhold a response. Participants completed a 10-trial practice block followed by 6 test blocks of 55 trials. Blocks presented either male or female faces and block order was randomized.

Updating indices. The task required participants to enter a new stimulus into WM while discarding an older stimulus to compare the new stimulus to the stimulus presented two trials earlier. There were nine trial types based on the updating operation (enter, discard) and the valence of stimulus (angry, happy, neutral). Indexes for updating in response to angry stimuli were calculated using match and no-match trials. Separate indices for discarding angry stimuli and entering angry stimuli were first computed (see Table 1), to construct an integrative index by dividing the WM discard index by the WM enter index. Higher scores reflected slower discarding and faster entering of angry information in WM.

Assessment of cognitive biases

Attention and interpretation biases were indexed using a procedure modeled after our earlier work (Everaert et al., 2014). Online attention bias was assessed using eye tracking while participants completed an interpretation task (a computerized version of the Scrambled Sentences Test; SST; Wenzlaff & Bates, 1998).

Stimuli. A set of 28 emotional and 15 neutral Dutch scrambled sentences was retrieved from Everaert et al. (2014). All sentences were self-relevant and six words long. Each emotional sentence contained one positive and one negative target word (e.g. “winner” and “loser” in “am I born loser a winner”). Target words were matched between valence categories on word length, class and word frequency using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004), all p -s>.05.² Word position within each sentence was randomized such that emotional target words were never presented next to each other nor as the first or last word in a scrambled sentence to control for parafoveal processing of adjoining words (Schotter, Angele, & Rayner, 2012) and wrap-up effects (Rayner, Kambe, & Duffy, 2000). These word order restrictions were also applied to neutral target words in neutral scrambled sentences.

Experimental task. Each trial of the SST started with a fixation cross presented at the left side of the screen until fixation. The following *stimulus display* presented either a neutral or an emotional scrambled sentence at the center of the screen (lowercase Arial, 25pt). Participants were instructed to unscramble the sentence mentally to form a grammatically correct and meaningful statement using five of the six words (e.g., “I am a born winner”), as quickly as possible. Upon completion, participants pressed a button to continue to the *response display*. In this trial part, each word of the scrambled sentence was presented with a number prompting participants to report their unscrambled solution verbally to the experiment

leader using the corresponding numbers. The display was presented until response or for a maximum of 8000 ms. Figure 1 depicts the flow of trial events.

After a 3-trial practice phase with neutral scrambled sentences, participants started the test phase presenting 40 scrambled sentences in 4 blocks. Each block contained 7 emotional and 3 neutral stimuli presented in a fixed random order. No more than two emotional scrambled sentences were presented consecutively to reduce priming effects. A cognitive load procedure was added to prevent voluntary report strategies and provide a purer measure of interpretive style (Rude et al., 2002). As in prior studies (Everaert et al., 2014), participants memorized a 6-digit-number before each block (presented 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.

Participants' gaze behavior was recorded during stimulus display trial parts via eye tracking. This enabled online measurement of visual attention while participants selected competing stimuli (e.g., “winner” and “loser” in “am winner born loser a I”) to interpret the emotional material (e.g., “I am a born winner” vs. “I am a born loser”). In line with prior work (Everaert et al., 2014), the total number of fixations on the target words in the scrambled sentences (i.e., the areas of interest) served as a dependent variable to index attention bias. Relative bias scores were calculated within-subjects. The total fixation frequency on negative words was divided by the total fixation frequency on positive and negative words in the emotional scrambled sentences. This bias index controls for inter-individual baseline fixation differences due to typical inter-individual variability in reading performance.

Eye tracker

A tower-mounted Eyelink 1000 eye tracking device (SR Research, Mississauga, Ontario, Canada) recorded gaze behavior, with eye-gaze coordinates sampling at 1000 Hz. Participants were seated approximately 60 cm from the display monitor. Visual fixations were

considered when longer than 100 ms because shorter fixations reflect anticipatory saccades (Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Stimulus presentation and eye movement recording were controlled by SR Research Experiment Builder.

Procedure

This study was part of a larger assessment battery to investigate relations between cognitive control over emotional material, cognitive biases, and emotion regulation in depression.³ Participants started with the cognitive biases assessment. A 9-point grid calibration procedure was repeated before each block of the SST and drifts from proper calibration were checked at the start of each trial. The experimenter registered participants' verbal responses (i.e., the coded unscrambled sentences and cognitive load number). After completion, participants completed the cognitive control tasks in another experimental room. The order of the cognitive control tasks was counterbalanced across participants. Finally, participants filled out the BDI-II to avoid mood priming. Participants were given the opportunity to take a short break between tasks to ensure optimal concentration. The session lasted approximately 1.5 hours.

Data preparation and analyses

Behavioral indexes were analyzed for the cognitive control tasks. First, inspection of accuracy rates identified 7 participants with extremely low accuracy rates on either the AST, $M_{\text{accuracy}}=26.75\%$ ($SD=2.98$), or the 2-back, $M_{\text{accuracy}}=27.25\%$ ($SD=14.24$), task. These participants were excluded from the analyses (final $N=112$; 95 women; 17–42 years; $M_{\text{accuracy}}=80.97\%$, $SD=8.37$). Second, the RTs on correct trials in the AST and 2-back task were normalized within each subject separately, to reduce the large inter-individual variability in overall motor responses associated with elevated depression levels. After excluding observations that deviated more than 3 SDs from an individual's mean across all trials, a z-score for each participant and trial type was calculated by demeaning the RT on a trial type

and then dividing by the *SD* of the RT distribution (Faust, Balota, Spieler, & Ferraro, 1999). This within-subject normalization leaves intact the relative relationship among RTs of all trials in each participant. Finally, all study variables were standardized to put them on the same metric.

The data-analysis involved multiple steps. First, zero-order correlations were inspected to examine associations between cognitive control over emotional material, cognitive biases, and depressive symptoms. Second, serial mediation models were tested using 5000 samples bias-corrected bootstrapping analyses. Bootstrapping is a nonparametric approach to estimate the magnitude and significance of the direct, total, and indirect effects. The estimated 95% bootstrap confidence intervals should not contain 0 to be significant (Preacher & Hayes, 2008). By relying on confidence intervals to determine the significance of the total, direct, and indirect effects, this statistical method avoids problems associated with traditional approaches (e.g., unrealistic assumptions regarding multivariate normality; Preacher & Hayes, 2008). The models were tested separately for inhibition, shifting, and updating operation, and included the cognitive control index as an independent variable, attention and interpretation biases as intervening variables, and depression levels as a dependent variable (see Figure 2). Evidence for an indirect effect model is provided by a significant indirect effect and both non-significant total and direct effects (Mathieu & Taylor, 2006).

Results

Sample characteristics

A mean score of 11.16 ($SD=9.98$) was observed on the BDI-II, and a mean of 6.18 ($SD=6.69$; range: 0-33) was observed on the DASS-A. A broad range of BDI-II scores was found (range: 0–49) with 74 individuals reporting minimal, 14 mild, 15 moderate, and 6 severe symptom levels. Scores from 3 individuals were missing due to partial completion of this questionnaire. The mean age was 21.84 years ($SD_{age}=4.20$; range: 17-42 years).

Correlational analysis

There were differential significant correlations between deficits in cognitive control over emotional material and cognitive biases. First, inhibitory control was correlated with attention bias, $r=-.28$, $p<.01$, but not with interpretation bias, $r=.03$, $p=.79$. Second, shifting was correlated with interpretation bias, $r=.26$, $p<.01$, but not with attention bias, $r=.02$, $p=.85$. Finally, updating was correlated with interpretation bias, $r=.20$, $p<.05$, and not with attention bias, $r=-.04$, $p=.70$. These correlations suggest that less inhibitory control over processing of negative material was associated with more negative attention bias and that negative interpretation bias was associated with difficulties in updating as well as shifting.

The indexes of cognitive control over emotional material were not related: Inhibitory control over angry information did not correlate with updating ability, $r=.14$, $p=.15$, nor with shifting ability, $r=-.01$, $p=.89$. Also updating ability was not related to shifting ability, $r=-.02$, $p=.85$. Attention bias was correlated with interpretation bias, $r=.29$, $p<.01$. Moreover, none of the indexes of cognitive control over emotional material were related to depression severity (all r 's between $-.12$ and $.13$, p 's $>.21$). Depression levels were related to interpretation bias, $r=.49$, $p<.001$, but not to attention bias, $r=.04$, $p=.66$.⁴ Anxiety levels were related to interpretation bias, $r=.29$, $p<.01$, but not to attention bias, $r=-.03$, $p=.74$, nor to cognitive control indexes (all r 's between $.02$ and $.11$, p 's $>.26$).

Bootstrapping analysis

Table 2 details statistics for the tested indirect effects and Figure 2 depicts the individual paths investigated.

Inhibition. The results supported the indirect effect of inhibitory control on depressive symptoms via attention bias and interpretation bias. No other indirect effects were significant. Neither the total effect, $c=.14$ ($SE=.10$), $t=1.36$, $p=.18$, 95%-CI: $[-.06, .34]$, nor the direct

effect, $c'=.12$ ($SE=.09$), $t=1.25$, $p=.21$, 95%-CI: [-.07, .30], of inhibitory control on depressive symptoms was significant.

Shifting. The results showed an indirect effect of shifting ability on depressive symptoms via interpretation bias. No other indirect effects were significant. Supporting this indirect effect, neither the total effect, $c=.13$ ($SE=.10$), $t=1.25$, $p=.21$, 95%-CI: [-.08, .33], nor the direct effect, $c'=-.01$ ($SE=.09$), $t=-.11$, $p=.91$, 95%-CI: [-.20, .18], of shifting ability on depressive symptoms was significant.

Updating. The results suggested an indirect effect of updating ability on depressive symptoms via interpretation bias. No other indirect effects were significant (see Table 1). Neither the total effect, $c=.14$ ($SE=.11$), $t=1.36$, $p=.18$, 95%-CI: [-.07, .35], nor the direct effect, $c'=.03$ ($SE=.10$), $t=.28$, $p=.78$, 95%-CI: [-.16, .22], of updating ability on depression severity was significant.

Alternative models. Further evidence for the proposed direction of effects was provided by the analyses testing alternative mediation models with deficits in cognitive control when processing emotional material mediating the relation between depressive symptoms and cognitive biases (attention bias, interpretation bias). For each cognitive control component, the 5000 samples bias-corrected bootstrapping analysis yielded no significant indirect effects. All 95% confidence intervals contained 0.

Discussion

Deficient cognitive control over emotional material and cognitive biases are potent cognitive factors in depression, but little is known about their interactions. In a theory-driven manner, this study tested serial mediation models with individual differences in cognitive control when processing negative information predicting depressive symptoms through attention and interpretation biases. The results showed that deficits in inhibitory control over negative material were related to attention bias which in turn predicted interpretation bias

which was subsequently associated with depressive symptoms. This finding supports the hypothesis that inhibitory control difficulties underlie negative biases in attention to regulate the interpretation of emotional material in depression (Joormann et al., 2007). Moreover, it was observed that both shifting and updating difficulties in response to negative material have an indirect effect on depressive symptoms through interpretation bias and not via attention bias. These findings are surprising in light of the hypothesis that cognitive control over emotional material exerts an influence via attention bias, but align with a prior study suggesting that attentional control modulates the interpretation of emotional material (Sanchez et al., 2015). However, that study did not disentangle components of cognitive control deficits in response to emotional material and does not speak to the relative contribution of the different components involved.

The present findings indicate that inhibitory control deficits were related to attention bias while both shifting and updating difficulties were related to interpretation bias. An explanation for these differential relations could be that, within the current experimental task context, the time course when difficulties in cognitive control over emotional material influence cognitive biases differs with respect to the specific component. As the findings suggest, inhibitory control difficulties bias allocation of external attention in favor of negative material while individuals create emotional meanings using the stimuli presented in the scrambled sentences. While this process of constructing different meanings would likely recruit strategic shifting and updating processes, the role of these processes at strategic stages could be minimized by the specific task conditions. First, the SST instructs participants to report the first meaning/sentence that comes to mind as quickly as possible, as such the task requires rapid activation of emotional representations rather than strategic elaboration on which meaning is most applicable. Second, the SST utilized a cognitive load procedure which leaves little room for strategic attention allocation or corrective processes, as such measuring

attention and interpretation biases at relatively automatic levels of processing. Thus, by biasing attention toward negative material, deficient inhibitory control over negative material may regulate the automatic activation of emotionally negative representations from memory (Hertel, 1997). Once a negative meaning is activated and held in WM, the difficulties in shifting and updating in response to this negative material may direct the focus of attention to the *internal* representation and hinder exploration of alternative meanings (not guiding *external* attention bias), resulting in an interpretation bias. Thus, during SST-trials, inhibitory processes may exert an influence during the automatic activation of meanings into WM, while shifting and updating may operate at later stages once the meaning is maintained in WM. Here, there is little room for shifting and updating abilities to guide external attention because individuals are explicitly instructed to report the activated meaning as quickly as possible. If individuals were explicitly instructed to elaborate on the different emotional meanings or the SST were completed not under load, the impact of deficient shifting and updating on external attention bias may have become more apparent.

In this study, difficulties in inhibitory control, shifting, and updating in response to emotional material had an indirect effect on symptom severity via cognitive biases and none of these control processes were directly related to depressive symptoms. This is surprising in light of prior research (De Lissnyder et al., 2010; Joormann et al., 2007; Levens & Gotlib, 2010; Zetsche & Joormann, 2011), though several studies also did not report evidence for such association but only a relation with rumination, a core feature of depression (e.g., De Lissnyder et al., 2010). Nevertheless, the relations between deficient cognitive control of emotional material and biases in attention or interpretation indicate that a particular cognitive control deficit remains of importance through its influence on interlinked cognitive biases that are related to depression (Everaert et al., 2014). This illustrates the importance of investigating different cognitive processes together in one design.

Another noteworthy finding was that the indexes of deficient cognitive control in response to emotional material were not correlated – though correlations would be expected if these processes reflected the same latent construct. Note, however, that the expectation to find correlations among valence-specific impairments in cognitive control over emotional material is based on research extracting the different components using data from cognitive control tasks presenting *neutral* stimuli (Miyake et al., 2000). The factor structure of ‘cognitive control over emotional material’ is currently less well investigated and it is not clear whether similar, correlated components could be extracted. This study is among the few investigations that examined relations among multiple cognitive control processes. Future largescale studies administering a multitude of tasks assessing cognitive control over emotional material are required to investigate the validity of typically distinguished components.

The results have implications for cognitive models of depression. The presented data provides evidence for the notion that difficulties in cognitive control over emotional material underlie cognitive biases related to depression (Hertel, 1997; Joormann et al., 2007) and prompts theorists to integrate these factors in established schema-based models of depression (e.g., Beck & Haigh, 2014). However, the current findings indicate that the interplay between cognitive control difficulties and cognitive biases may be more complex than is currently proposed. The interplay between deficient cognitive control in response to emotional material and cognitive biases may vary with the components and task conditions under investigation. Theoretical advancements should be informed by more integrative research considering multiple aspects of cognitive control when processing emotional material and cognitive biases.

This study has implications for the delivery of methods targeting information-processing abnormalities to reduce depressive symptoms. The indirect effects suggest that cognitive control training during the processing of emotional material may be useful at

reducing depression symptoms through its relation with cognitive biases (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013). Note, however, that this study is the first to model relations among deficits in multiple components of cognitive control in response to emotional material and cognitive biases. The results require replication as well as longitudinal research and experimental manipulation to test the causal direction of the effects.

This study has several limitations. First, the cognitive control tasks employed in this study may not have provided “process-pure” indexes of inhibition, shifting, or updating. That indexes drawn from cognitive tasks may reflect multiple cognitive control components is a known difficulty characteristic for many experimental tasks. Nevertheless, the tasks applied here have been repeatedly shown to provide a sensitive estimate of the components it aims to measure (De Lissnyder et al., 2010; Levens & Gotlib, 2010; Whitmer & Banich, 2007). Second, this study investigated difficulties in cognitive control processes in response to emotional information and, therefore, the current findings may not generalize to general cognitive control processes that operate on emotionally neutral stimuli. Third, the cross-sectional design of this study precludes claims regarding causality. This study is a first step to obtain a clearer view on the relations between distorted cognitive processes and depressive symptoms, which could guide more intensive research using multiwave longitudinal designs or experimental manipulations to substantiate the hypothesized causal relations. Finally, the study was conducted in a nonclinical sample which may limit generalizability of the findings to clinical samples. As noted, this sample types was deliberately chosen given the demanding study protocol.

Conclusion

This study provides evidence for several indirect effects of difficulties in cognitive control over emotional material on depressive symptoms via cognitive biases in attention and interpretation. The indirect effects varied in function of the cognitive control component and

cognitive bias under consideration. More integrative research investigating relations among these cognitive factors is required in order to formulate comprehensive theories of the cognitive foundations of depression.

Footnotes

¹ The number of presentations of each trial type did not significantly differ ($M=34.00$; $SD=0.92$; range: 32.56 – 34.81), all p 's $>.05$.

² Word length: $M_{\text{negative words}} = 8.79$ ($SD_{\text{negative words}} = 1.71$), $M_{\text{positive words}} = 8.58$ ($SD_{\text{positive words}} = 1.97$); Word frequency (log frequency per million): $M_{\text{negative words}} = 1.02$ ($SD_{\text{negative words}} = 0.47$), $M_{\text{positive words}} = 1.04$ ($SD_{\text{positive words}} = 0.62$).

³ In addition to the measures reported in this article, the participants completed two emotion regulation questionnaires of positive reappraisal and rumination after the cognitive biases assessment and before the questionnaires. The results on the relations among cognitive biases and emotion regulation are reported elsewhere.

⁴ Depression levels were not correlated with the total fixation frequency on neutral words, $r=-.03$, $p>.05$, suggesting that baseline fixation patterns, and reading times, did not differ as a function of depression severity.

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Figure 1. Schematic depiction of the flow of trial events in the cognitive biases assessment task.

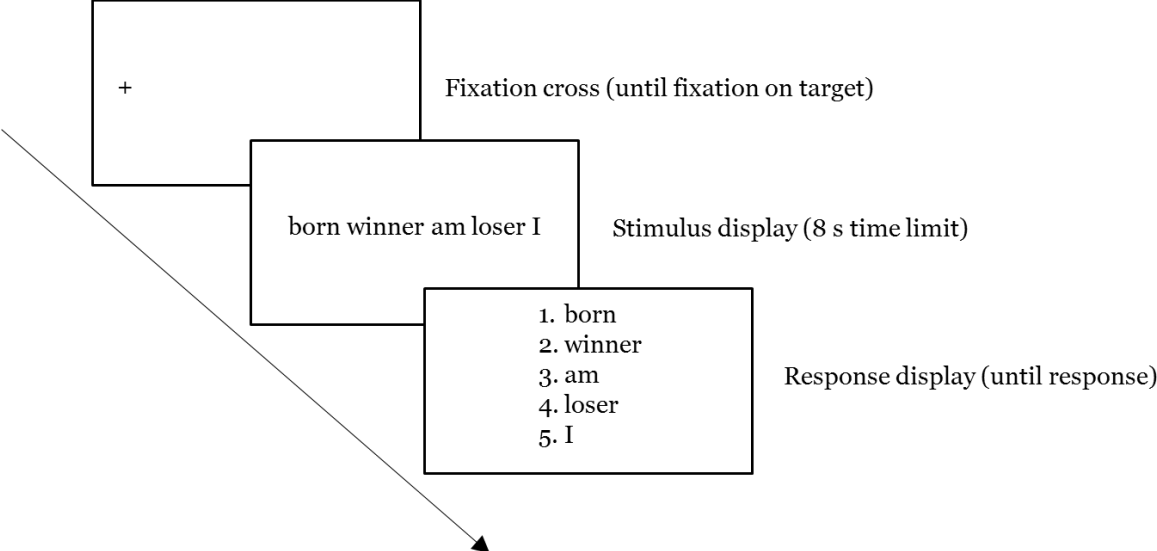


Table 1. *Cognitive control task trials and indexes.*

Affective Shift task			
<i>Trial types</i>			
	Cue trial 1 (n-2)	Cue trial 2 (n-1)	Cue trial 3 (n)
48 Inhibitory trials (a–b–a)	emotion gender color	gender or color emotion or color emotion or gender	emotion gender color
48 Control trials (c–b–a)	gender (color) color (emotion) gender (emotion)	color (gender) emotion (color) emotion (gender)	emotion gender color
48 Unclassified trials (b–b–a)	gender (color) emotion (color) emotion (gender)	gender (color) emotion (color) emotion (gender)	emotion gender color
72 Repeat trials (a–a)		emotion gender color	emotion gender color
<i>Indexes</i>			
Inhibition index	RT to inhibitory trials on which participants ignored angry faces on cue trial n-2 and focused on angry faces on cue trial n – RTs to inhibitory trials on which participants ignored angry faces on both cue trial n-2 and n. A higher score indicates better inhibitory control over angry information.		
Shifting index	Control, unclassified, and repeat trials were considered. (RTs to trials with shifts from emotion-angry to a non-emotional dimension – RTs to emotion-angry repeat trials) / (RTs to trials with shifts from gender to emotion-angry – RTs on non-emotional repeat trials). A higher score reflects slower shifting from and faster shifting to negative material.		
Emotional 2-back task			
Trial types of interest	discard-angry/enter-neutral, discard-neutral/enter-neutral trials, discard-neutral/enter-angry		
<i>Indexes</i>			
WM discard negative material	RT to discard-angry/enter-neutral trials – RT to discard-neutral/enter-neutral trials		
WM enter negative material	RT to discard-neutral/enter-angry trials – RTs discard-neutral/enter-neutral trials		
Integrative updating index	Index WM discard negative material / Index WM enter negative material. A higher score reflect slower discarding and faster entering of negative information in WM.		

Notes. To compute the integrative indexes, the individual indexes were first transformed such that the minimal value on each variable was 1.

Table 2. *Bootstrapping results.*

Indirect effect	Coefficient	SE	95%-CI
(1)	.0157	.0318	[-.0398, .0902]
(2)	-.0459	.253	[-.1215, -.0125]
(3)	.0512	.0575	[-.0315, .2055]
(4)	-.0024	.0152	[-.0415, .0193]
(5)	.0028	.0141	[-.0238, .0356]
(6)	.1378	.0740	[.0324, .3343]
(7)	.0045	.0149	[-.0125, .0629]
(8)	-.0061	.0142	[-.0418, .0192]
(9)	.1167	.0673	[.0225, .2882]

Note. (1) inhibitory control → attention bias → depressive symptoms; (2) inhibitory control → attention bias → interpretation bias → depressive symptoms; (3) inhibitory control → interpretation bias → depressive symptoms; (4) shifting ability → attention bias → depressive symptoms; (5) shifting ability → attention bias → interpretation bias → depressive symptoms; (6) shifting ability → interpretation bias → depressive symptoms; (7) updating ability → attention bias → depressive symptoms; (8) updating ability → attention bias → interpretation bias → depressive symptoms; (9) updating ability → interpretation bias → depressive symptoms. Significant indirect effect models are in bold.